

STATE OF HAWAII **CORAL REEF** PROGRAM



February 2015

www.dlnr.hawaii.gov/coralreefs

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Hawai`i Coral Reef Program

February 2015 Update

The mission of the Division of Aquatic Resources (DAR) is manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations.

Coral reefs are critical ecosystems that possess immense ecological, economic, and cultural value. Coral reefs provide food, jobs, recreational opportunities, coastal protection, and other important services for our islands.

Threats to coral reef ecosystems include increasing sea surface temperatures, land-based sources of pollution, overfishing, crown of thorns starfish, and recreational misuse.

DAR manages coral reefs through restoration, regulation, and community and stakeholder engagement.

Hawai`i Coral Reef Strategy

The Hawaii Coral Reef Strategy is the guiding coral reef management document used by the Hawai`i Division of Aquatic Resources, implemented with support from the NOAA Coral Reef Conservation Program as well as numerous agency, non-governmental organization, academic and community partners.

Objectives

1. Reduce key anthropogenic threats to two priority near-shore coral reef sites by 2015 and five by 2020 using ahupua`a based management.
2. Prevent new AIS introductions and minimize the spread of established AIS populations by 2020.
3. Increase the abundance and average size of five targeted coral reef fisheries species critical to reef health and ecological function by 2020.
4. Designate a sufficient area of marine waters under effective conservation by 2020 to ensure sustainable and resilient coral reef ecosystems.
5. Reduce anchor damage and trampling on coral reefs through the implementation of no anchor zones, utilization of day use mooring buoys and other means by 2020.



Coral Reef Strategy Priority Areas



Vision: A restored, healthy, abundant and resilient South Kohala coastal system cared for and cherished by and island community guided by the values and traditions of South Kohala.

Recent Projects:

- Stream corridor assessment
- Ungulate exclusion and sediment reduction
- Understanding impacts of land based nutrients on coral reef health
- Coral settlement distributions and environmental conditions
- Traditional community based moon calendars



Vision: To restore and enhance the health and resiliency of West Maui coral reefs and near-shore waters through the reduction of land-based pollution threats from the summit of Pu`u Kukui to the outer reef. These efforts will be guided by the values and traditions of West Maui.

Recent Projects:

- Curb inlet basket installations
- Rain gardens at beach parks
- Reef Friendly Landscape Management plans
- Post-fire rehabilitation planning
- Constructed wetland analysis and design
- Design analysis for dam retrofit

Regulations



DAR enacts regulations included, managed areas, seasonal restrictions, and bag and size limits. Recent rule changes include:

Managed Species

- Increased protection for coral and live rock including from land-based sources adopted in 2014
- Updated bag and size limits for parrotfishes and goatfishes for Maui county intended to protect adopted in 2014

Managed Areas

- Aquarium fishing “white list” and prohibition of scuba-spearfishing in West Hawaii adopted in 2013
- Hā`ena community-based subsistence fishing area approved in 2014

Community Co-Management

Starting in 2013, DAR started growing community co-management approaches for stewardship of nearshore marine ecosystems. Community co-management includes programs, processes, and tools that engage and empower communities in understanding and stewarding shared resources.

Why community co-management in Hawaii?

1. More responsive to people's needs
2. Incorporates multiple knowledge sets and resource use needs
3. Improved understanding and better buy-in for outcomes
4. Well suited to coral reef fisheries with lots of small-scale users and large spatial, temporal, demographic variation in target species, gear and other variables



DAR is working to develop and implement community-based subsistence fishing area rules and to grow the Makai Watch program that trains communities to accurately report violations and to conduct outreach and monitoring.

Coral Reef Restoration and Mitigation



Reef Restoration

The State of Hawai'i, with our partners from UHM and TNC have been restoring Kaneohe patch reefs by manually removing invasive algae that was smothering reefs and out-planting native urchins as a bio-control.

Coral Mitigation Bank

Currently DAR is working to establish the first coral mitigation bank applying these methods which have been refined over the past decade.

West Maui Priority Area Projects



What is the West Maui Ridge to Reef Initiative?

The West Maui Ridge to Reef (R2R) Initiative is an all-encompassing approach across multiple agencies and organizations to address adverse impacts to coral reefs in West Maui. The State recognized that an integrated and comprehensive approach to reduce land-based sources of pollution is one of the most important steps to help restore coral reef ecosystems. The R2R Initiative builds on already established efforts underway and leverages resources across a number of agencies and community groups to implement actions to reduce one of the key sources of reef decline – land-based sources of pollution.

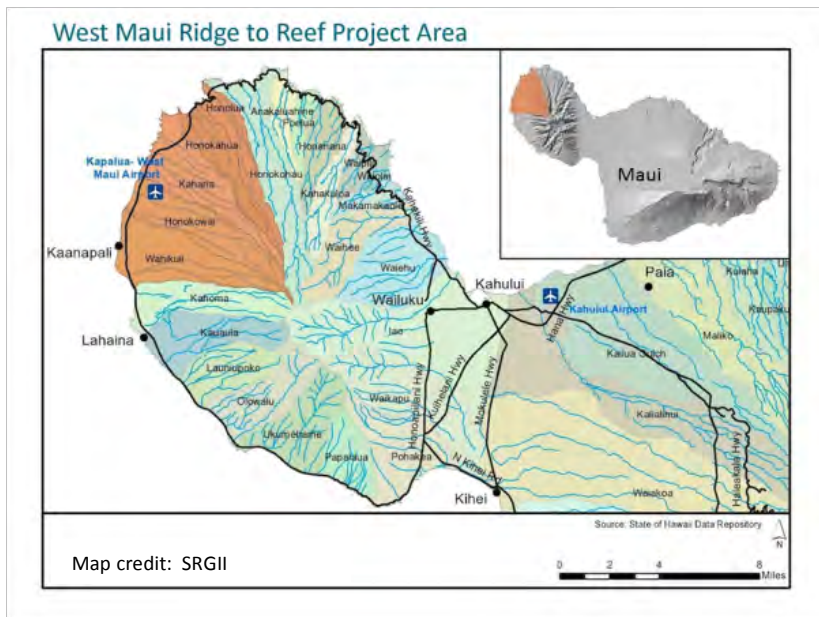


Photo credit: Liz Foote

R2R Objective

To restore and enhance the health and resiliency of West Maui coral reefs and near-shore waters through the reduction of land-based pollution threats from the summit of Pu`u Kukui to the outer reef. These efforts will be guided by the values and traditions of West Maui.

R2R Project Area



Priority Status: The Hawaii Coral Reef Strategy identified the coral reef ecosystem along the West Maui region as a priority management area. The US Coral Reef Task Force designated the West Maui Watershed as a priority partnership in the Pacific in 2011, focusing on Wahikuli and Honokōwai watersheds. The full R2R project area includes 24,000 acres from Kā`anapali northward to Honolua and from the summit of Pu`u Kukui to the outer reef.

Ongoing and future work: The watershed management plan for Wahikuli and Honokōwai was completed in Dec. 2012 and is now in the implementation

phase. Planning for Kahana, Honokohua and Honolua watersheds is underway and will be completed by 2015. The draft watershed management plan for the next phase is expected to be completed by the end of 2014.

For more information, please contact the West Maui Watershed & Coastal Management Coordinator,
Tova Callender – 214-4239, tova@westmauir2r.com

Local Advisory Body- R2R Working Group



The Working Group supports the R2R Initiative by serving as a local body providing community input to the FAST (see below). Its members represent key interests in West Maui, such as agriculture, land development, resort operation, soil conservation, traditional Native Hawaiian knowledge, non-profit marine conservation, recreational ocean users, Maui County and fishing. (Pictured from left to right: Wayne Hedani, Liz Foote, Chris Brosius, Wes Nohara, Pomaika'i Kaniaupio-Crozier, Russell Sparks, Felimon Sedang and Ekolu Lindsey. Missing: Rob Parsons & Jeff Rebugio)

Lead Partner Agencies & Organizations



These partner agencies and organizations form the Funding and Agency Support Team (FAST), which is the leadership body for the Initiative. The FAST meets monthly to provide oversight in managing funds, prioritize activities and develop strategies to achieve the R2R goals. More information about the R2R can be found at the website- www.westmauiR2R.com.

Contacts:

Project Manager, West Maui Watershed Study: Athline Clark, USACE: Athline.M.Clark@usace.army.mil
State of Hawaii Contact: Emma Anders, DLNR DAR: Emma.Anders@hawaii.gov

Completed & Ongoing Pollution Reduction Projects in West Maui

- Curb inlet basket installations
- Rain Gardens at beach parks
- Reef Friendly Landscape Management plans
- Post-fire rehabilitation planning
- Constructed wetland analysis and design
- Design analysis for Dam Retrofit
- Agricultural road improvement



Rain Garden at Wahikuli Wayside Park

West Maui Kumuwai- A Social Marketing Approach to Action

West Maui Kumuwai is committed to protecting what we love: the ocean and our way of life here on West Maui. Our focus is on reducing land-based sources of pollution through personal action and community collaboration.

We shine a spotlight on the actions of everyday people and community heroes to promote the health of our ocean. We tell stories about what's happening in our community. We hold events where you can lend a hand alongside your neighbor. But most of all, we offer ways in which you can help curb the amount of pollutants that are harming our ocean—and we try to make those actions easy enough to do. We're talking about things that you can do at home or in your yard, like the type of fertilizer you use or picking up after your pooch. For more information: www.westmauikumuwai.org



Mission: The mission of the Hawaii Division of Aquatic Resources (DAR) is to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations.

The DAR manages the state's aquatic resources and ecosystems through programs in ecosystem management, place-based management, and fisheries management. Major program areas include projects to:

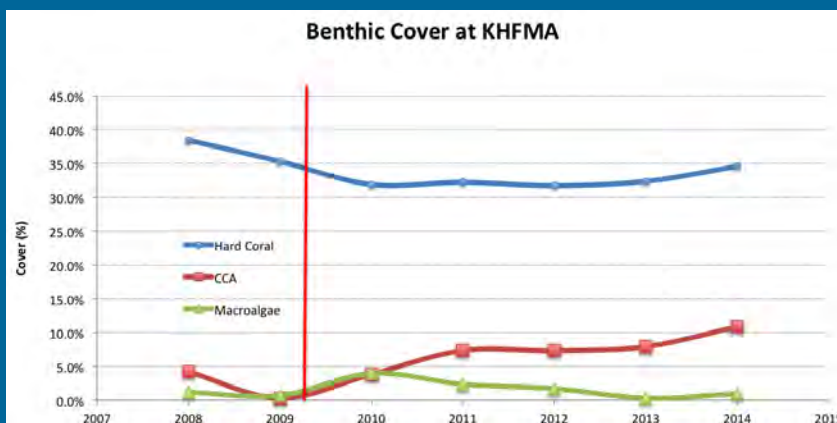
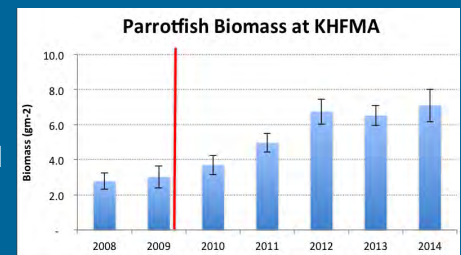
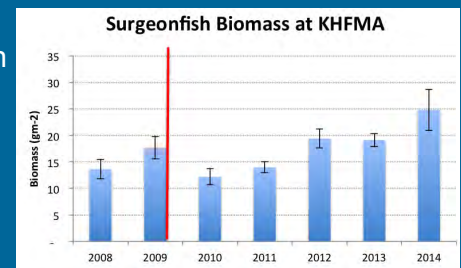
- protect and restore the aquatic environment;
- protect threatened and endangered aquatic species and their habitat;
- conserve and restore endemic and indigenous aquatic species and their habitat;
- combat the introduction of invasive species and reduce their impact on ecosystems;
- effectively manage fisheries; and
- carry out education and outreach to the public.

Kahekili Herbivore Fisheries Management Area

Background: The Kahekili Herbivore Fisheries Management Area (KHFMA) was established by DAR in 2009 to control the overabundance of alien and native marine algae by increasing the abundance of herbivorous fishes and sea urchins. Under KHFMA rules, it is illegal to take any herbivorous species and fish feeding is prohibited.

2014 update:

- Increasing trend of surgeonfishes biomass. Biomass increased 40% 2009 – 2014
- Consistent upward trend in parrotfishes biomass, which has more than doubled since 2009.
- Increased parrotfish biomass in the shallow, nearshore reef areas, which had previously shown few signs of recovery.
- Coral cover has marginally increased in 2014 and CCA has shown a strong upward trend.



Looking Ahead: The recent small upturn in coral cover may be an early sign that protection of herbivores is leading to improved conditions for coral growth and survival in the KHFMA. It is very important to recognize the full effects of herbivore protection on fishes and benthic conditions will only become clear over longer time frames.

Wahikuli-Honokōwai Agricultural Road Drainage Improvement Project

West Maui Soil & Water Conservation District, Sept.30, 2014

PROJECT OVERVIEW

This pilot project worked on two stretches of agricultural roads in Wahikuli and Honokōwai watersheds that were identified as problem areas for sediment erosion leading to stress on coastal ecosystems. Working with landowners and an engineer, specifications were created for where the construction contractors should put water bars, and reestablish terraces. Improvements were made to 3.2 miles of road and have resulted in more functional water diversion systems that will slow and divert run-off and sediment accumulated in rain fall events, preventing it from continuing into the gulches and down to coastal waters where it stresses reefs. The capacity of two local contractors has been increased, and this pilot scale project has facilitated an understanding of the steps that will be required for the larger-scale Phase II project to follow this fall.

PROJECT GOALS AND OBJECTIVES

Goal: To improve coastal water quality and coral ecosystem function and health by reducing land-based pollution.

Objective: Reduce pollutant load to surface water and groundwater through site-specific actions and best management practices on two sections of eroding agricultural roads. Specifically;

1. Solidify the relationships and build local equipment operator capacity in maintaining road BMPs.
2. Reduce the amount of sediment generated off two earthen access road surfaces and associated terraces.
3. Reduce sediment loads carried by the road network to the near-shore ocean waters.

RESULTS

- *Improvements were made on 3.2 miles of eroding agricultural land*
- *On Puka Camp Rd. in Dept. of Hawaiian Home Lands, 1.7 miles of road was improved and ~6000 linear feet of terraces were opened and modified from a traditional design to a reef friendly design by preventing hydrologic connectivity to the gulches*
- *On General Finance Group road, 1.5 miles of road was improved by grading, and through the addition of water bars at specified intervals to allow the energy of the water and accumulated sediment to dissipate into the fields*



Example of water bar to dissipate water and sediment into the field in Wahikuli watershed

MANAGEMENT OUTCOMES

1. *Capacity of local contractors to install and maintain earthen road BMPs was increased.*
2. *Project steps were piloted to inform larger scale effort to follow funded by EPA/DOH which will be able to address the majority of eroding earthen roads in Wahikuli and Honokowai.*

Sediment Retention at Honokōwai Structure #8

Dr. Roger Babcock, October 2014

PROJECT OVERVIEW

The Honokowai watershed has been listed as a priority of concern in the NOAA R2R Initiative. Honokōwai Structure #8 consists of a dam and debris basin that impounds and detains the flow of Honokōwai Stream. The existing structure delivers fine sediment, coarse debris, and other pollutants to coastal waters and coral reefs via two pathways:

- A concrete outlet structure located near the bottom of the basin that contains eight openings to contain and slowly release low magnitude runoff events (≤ 2 year recurrence interval) and a large primary spillway box that discharges larger runoff events (> 2 -yr and < 100 -yr), and
- Runoff from extreme storm events (≥ 100 -yr) that passes through the unlined erodible channel of an emergency spillway.

This project considered design alternatives that might increase the trapping efficiency of the reservoir through modification of the current dam structure.

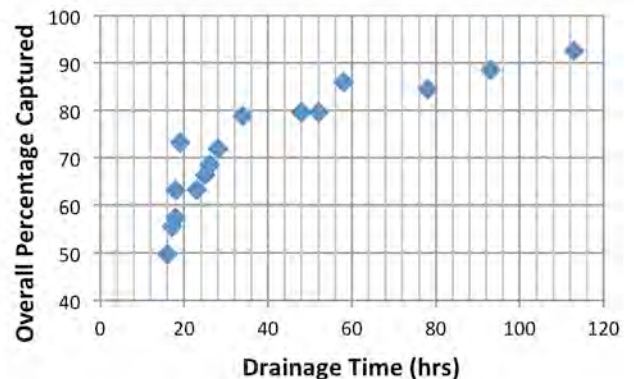
PROJECT GOALS AND OBJECTIVES

The objectives of the project were as follows:

- 1) Reevaluate Honokōwai watershed hydrology, original debris basin design parameters, and existing basin characteristics, operations and performance;
- 2) Establish a monitoring program to collect field data for evaluation of the hydrological model
- 3) Analyze potential trapping efficiency and sediment retention for a suite of design alternatives;
- 4) Analyze potential trapping efficiency and sediment retention for current and future land use; and
- 5) Evaluate the cost-effectiveness, dam safety ramifications, and hydrologic impacts of various retrofit approaches in reducing basin-delivered sediment loads.

RESULTS

- Using a watershed model called GSSHA, - predicted total sediment flows ranged from approximately 1,000 to 45,000 tons for 2- and 100-yr statistical storms, respectively.
- Simulations found that for the current land use scenario, the as-built overall sediment trapping efficiency of the basin is between 50% and 36% for the 2- and 100-yr storm events.
- All larger storms were estimated to pass over the primary spillway and were not predicted to be highly affected by structural modifications.
- The recommended modification scenario can be accomplished by installing plates over all eight of the existing 12' x 24" openings with the upper 6 plates containing 6" diameter openings. This would increase the trapping efficiency to 84% for current land use, and 74% for future land use.



Overall Sediment Capture Rate vs Drainage Time: 2-Year Storm, Current Land Use, As-Built Basin

MANAGEMENT OUTCOMES

- The main product of this project was a comprehensive technical report describing in detail the methods and results of our research to be distributed to the Maui County Department of Public Works to assist in planning efforts.
- As Honokowai #8 Reservoir has a similar design to seven other reservoirs in the islands built around the same time for a similar purpose, including Kahana Reservoir in Kahana watershed, these analyses can be replicated for other reservoirs based on the same method.

PROJECT OVERVIEW

As described in the *Wahikuli-Honokōwai Watershed Management Plan*, non-point source (NPS) pollution from urban areas impairs nearshore water quality causing stress to coral reefs. The Plan identified Curb Inlet Baskets as a management measure to reduce NPS pollutants entering the storm drain system. A Curb Inlet Basket is designed to capture NPS pollutants in stormwater runoff as it enters the storm sewer. Cleaner water leaves the basket and travels through the system.

This project was a pilot project in the West Maui region to evaluate both process (installation, maintenance) and performance. The cumulative impact of installing Curb Inlet Baskets in the West Maui region will be a reduction in NPS pollutant loads affecting nearshore waters and coral reefs.

PROJECT GOALS AND OBJECTIVES

The overarching goal of this project was to provide a long-term reduction in NPS pollutant loads affecting nearshore waters and coral reefs by

- successfully installing seven Curb Inlet Baskets in the West Maui region;
- establishing and conducting a maintenance routine;
- documenting project successes and challenges as a pilot effort; and
- educating users (current and future) of the benefits of Curb Inlet Baskets and their low maintenance requirements.

RESULTS

- *Successful installation of seven Curb Inlet Baskets to reduce non-point source pollutant runoff.*
- *Even with challenges, installation and maintenance requirements are manageable.*
- *Land owner cooperation and commitment to on-going maintenance is essential for success.*
- *Pilot project provided valuable information for planned larger scale installation.*



Curb Inlet Basket Locations

MANAGEMENT OUTCOMES

This project demonstrates, on a pilot scale level, that implementation of Curb Inlet Baskets as management practices to reduce NPS pollution loads and protect coral reef ecosystems is feasible. Lessons learned from this project should be shared with others, and used to expand their installation in the West Maui region as recommended in the *Wahikuli-Honokōwai Watershed Management Plan*.

For More Information

Tova Callender, tova@westmaui2r.com

www.westmaui2r.com

www.westmauikumuwai.com

www.hawaiicoralreefstrategy.com

Reef Friendly Landscape Management Plan

Tomo Murata, October 17,
2014

PROJECT OVERVIEW

The West Maui Ridge to Reef Initiative was launched in 2012 to focus upon addressing causes of land based pollution that are currently believed to be deteriorating our marine systems. As one of several partners in the initiative, the project developed seven landscape management plans. These management plans address the resorts need for aesthetically pleasing grounds while implementing best practices that minimize the use of pesticides, fertilizers, and irrigation water. The Reef Friendly Landscape Management Plan is a product of collective knowledge of field personnel, landscape professionals, chemical distributors, and participating resorts. It is intended to serve as a guideline and best management practices for participating resorts to adopt into their reef friendly landscape maintenance operations.

PROJECT GOALS AND OBJECTIVES

The goal of Reef Friendly Landscape Management Plan is to show that healthy and beautiful landscapes can coexist with healthy and diverse coral community in Kā'anapali by integrating the following practices:

- Reduce chemical input into coastal water
- Reduce waste
- Reduce water & energy consumption
- Reduce runoff/erosion (retain topsoil)
- Improve soil environment to reduce fertilizer applications
- Create sustainable/harmonious landscapes
- Protect wildlife habitats
- Increase native plants and diversity
- Utilize integrated pest management to minimize chemical use

RESULTS

- Reef Friendly Landscape Management Plans
- Recommended Reef Friendly Landscape Management Practices
- Guidelines for Reef Friendly Operation & Maintenance Checklist



Figure 1 Project Area Map

MANAGEMENT OUTCOMES

The project produced Reef Friendly Landscape Management Plans that contains guidelines and checklists so that the seven participating resorts can implement the Plans to improve their maintenance while reducing chemical outputs to the environments. Now the additional work or the future follow up is needed to see how effective the plans are in terms of the water quality.

West Maui Wildfire Mitigation Planning

Elizabeth Pickett, Executive Director
Hawaii Wildfire Management Organization
October, 2014

PROJECT OVERVIEW

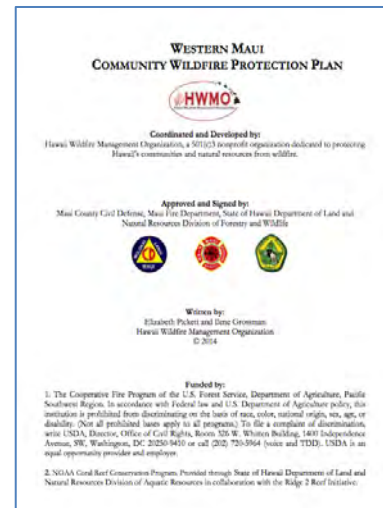
Wildfire threats are imminent and can have widespread damage that potentially affects all properties within Western Maui, including Honokowai and Wahikuli Watersheds. To better plan and prepare for wildfire at multiple scales and timeframes in West Maui and Wahikuli-Honokowai, Hawaii Wildfire Management Organization (HWMO), worked with private land owners, the West Maui First Task Force, and local and state Fire Prevention personnel to develop a Western Maui Wildfire Protection Plan and a Wahikuli-Honokowai Wildfire Mitigation Plan for pre-fire and post-fire actions to reduce wildfire impacts.

RESULTS

- *The Western Maui Community Wildfire Protection Plan is available at Hawaiiwildfire.org and can be used as a reference to develop wildfire-related projects across Western Maui.*
- *It is crucial that the lands within the Wahikuli-Honokowai watersheds are managed for wildfire hazard reduction*

PROJECT GOALS AND OBJECTIVES

- 1) Complete a Community Wildfire Protection Plan for West Maui to establish an understanding of fire threat and resources needed to address to enable community and agency preparedness in the event of a wildfire;
- 2) Develop a plan that provides recommendations for how to reduce wildfire hazards and decrease likelihood of wildfire ignition and spread in Wahikuli-Honokowai.
- 3) Develop a plan to aid landowners and manager sin Wahikuli-Honokowai to prepare ahead of time for a strong post-fire response (ultimately to reduce erosion and other post-fire damage).



The Western Maui CWPP is available to the public at:
[www. Hawaii Wildfire.org](http://www.HawaiiWildfire.org)

MANAGEMENT OUTCOMES

Resource managers now have a comprehensive list of wildfire-related concerns, priorities, and projects that were collaboratively discussed and developed across Western Maui. These are intended to be used as a basis from which decisions and projects to mitigate wildfire are based. Similarly, the Wahikuli-Honokowai watersheds have now undergone a detailed assessment for management activities that can be implemented to reduce wildfire risk. The Wahikuli-Honokowai Wildfire Mitigation Plan is intended for use by managers to reduce wildfire hazard and risk.

Rain Garden Design, Installation and Signage at Pohaku Beach Park, West Maui

Lauren Campbell, 10/20/2014

PROJECT OVERVIEW

Pohaku Beach Park is a popular surfing and family-friendly park on the island of Maui. It sits directly on the ocean, and includes numerous hardscapes such as a large parking lot and a nearby roadway, as well as a public shower. Without appropriate drainage, unfiltered pollution runs from the park's hardscapes directly into the ocean and near shore reef.

Surfrider Foundation Maui Chapter planned, designed and installed two separate rain gardens at the park – one to drain the North area's parking lot and a second garden to drain the South area's public shower.

On September 6, 2014, Surfrider Foundation Maui Chapter and community members successfully installed the two gardens, complete with compost, mulch and native plants. The South Garden is 286 sq. ft, and the North Garden is 466 sq. ft. The design is straightforward, efficient and beautiful: slowing down, spreading out and sinking water into planted swales so it can be filtered and absorbed by soil, plants and mulch.

PROJECT GOALS AND OBJECTIVES

Primary Goals

1. Improve near-shore ocean and coral reef health by installing two rain gardens at Pohaku Beach Park to capture and filter polluted runoff.
2. Enhance community awareness about the issues of urban runoff and reef decline, while also involving the community as part of the solution.

Secondary Goals

1. Assist in streamlining future rain garden projects by engaging County permitting agencies in the rain garden design and installation process.
2. Develop a model rain garden to demonstrate to resource managers an effective, community-based solution to localized, ocean pollution.
3. Build capacity within Surfrider Maui so as to spearhead future rain garden projects.

RESULTS

- *Installation of two rain gardens at Pohaku Beach Park that total 752 square feet and will annually drain an estimated 30,000 gallons of water.*
- *Enhanced public knowledge about urban runoff and the role of rain gardens through interpretive signage, onsite demonstrations and social media.*
- *Development of a model rain garden that can be used to guide future projects on Maui.*
- *Enhanced capacity within the Surfrider Foundation Maui Chapter organization to spearhead future rain garden projects.*



Figure 1: (Clockwise from top left) South Garden before; South Garden after; North Garden before; North Garden after

MANAGEMENT OUTCOMES

The Pohaku Beach Park project serves as a model rain garden project for local resource managers. The project demonstrates an effective, community-based solution to localized, ocean pollution. Moving forward, resource managers can build upon the project and work with Surfrider (and other organizations) to establish a network of rain gardens throughout Maui. Especially in areas of significant reef decline, these gardens will help enhance the health of Maui's near shore waters in a cost effective manner that also involves the local community.

Three Month Continuation of West Maui Kumuwai Campaign

Tova Callender, Sept.30, 2014

PROJECT OVERVIEW

The West Maui Kumuwai campaign reduces polluted runoff entering near shore waters in West Maui that may lead to algae blooms and coral decline by persuading area residents to play an active role in ensuring the health of their watershed.

After the West Maui Kumuwai social marketing campaign was developed with support from NOAA and expertise from SeaWeb in 2013, the challenge was to keep up the momentum needed to build the campaign and keep it in the public consciousness. Through this additional support, targeted actions were enabled that increased engagement and awareness of the campaign. These actions included soliciting pledges for personal actions, multiple community volunteer events, sustained media and social media presence, and increased enrollment in the Ocean Friendly Landscaper program.

PROJECT GOALS AND OBJECTIVES

Goals: Through specific social marketing approaches, the campaign strategy is designed to generate not just individual actions in the short term, but a behavior change path that leads to greater, more complex actions and commitments (from individuals and the larger community) to sustainably manage West Maui reefs for the long term.

Objectives:

To increase the traction and participation in Kumuwai programs that has been developed, specifically: Increase pledges, hold community events, increase participation in ocean friendly landscapers, conduct outreach to the Maui Association of Landscape Professionals, increase sales in Ocean Preferred Products, complete additional community stories, increase social media engagement and get media coverage in local papers.

RESULTS

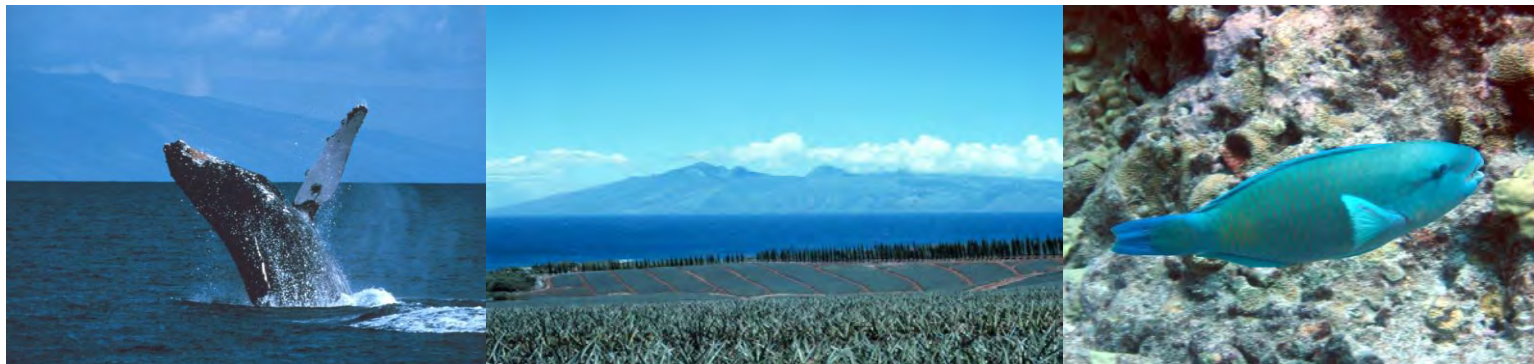
- *Three community events were held, engaging ~200 community members in rain garden creation, a reef clean up and educational activities.*
- *Three new properties signed up for the Ocean Friendly Landscaper program adding 108 acres.*
- *40 personal pledges for actions for ocean health were made.*



West Maui Kumuwai & Surfrider Foundation, Maui came together with ~40 volunteers to build two new rain gardens at Pohaku Beach Park in September, 2014

MANAGEMENT OUTCOMES

This effort supports management outcomes in two ways; actual reductions in polluted runoff through individual action, and as importantly, increased awareness and caring about the health of our marine resources and our role in addressing decline. Given the small, interconnected nature of the community, this awareness translates to more support for the larger pollution reduction efforts underway through the R2R Initiative.



WHAT IS THE MAUI COASTAL USE MAPPING PROJECT?

The **Coastal Use Mapping Project** is designed to fill a critical information gap in ocean management by mapping significant human uses of the nearshore ocean area in the Honolulu – Wahikuli region. The intent is to gain a better understanding of the spatial range and intensity of key human activities and use-types in this region in order to better inform resource management. To this end, a participatory mapping workshop will be held where local resource users, scientists, and stakeholders will create maps of ocean uses. Data, maps and analytical products will be made available to local community groups, state and federal agencies, NGOs, and to other interested parties.

WHY NOW, AND WHY HONOLUA - WAHIKULI.

Coral reefs in Hawai'i are facing increasing pressures from a growing variety of ocean uses, as well as increased coastal development and watershed impacts. The Coastal Use Mapping Project is intended as a first step to improving regional coastal and watershed management activities. The baseline information collected through this project will provide a better understanding of human uses, issues, and constraints in these regions. It can help inform managers so they can make management decisions to better protect the ecosystem, while minimizing impacts on those who depend on marine resources and reducing user conflict. The project includes collecting and mapping existing watershed information, conducting a participatory mapping workshop, and follow-up stakeholder interviews to gain a more in-depth understanding of human uses and use motivations that affect the region. Through this process we hope to answer the questions:

- Who are the primary resource users in the region?
- Where do activities take place, and where is activity most concentrated?
- To what extent do different user-groups rely on local coastal/marine resources?
- When do different activities take place?
- What are the observed impacts of different uses?
- What local management activities are already in place?
- Where is there a potential for user conflicts?
- What are the perceived problems (and potential solutions) in the region?
- What are potential opportunities for management action?

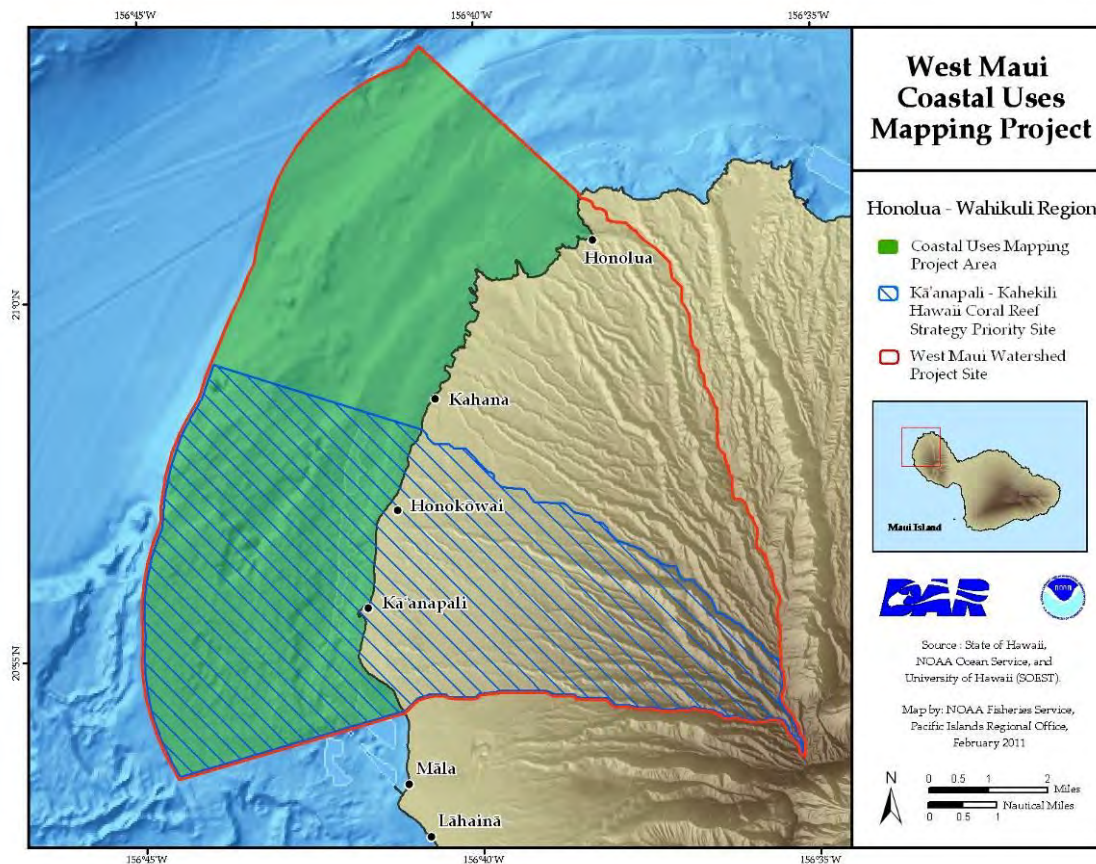
WHO IS SPONSORING THE MAPPING PROJECT?

The Maui Coastal Use Mapping Project is a partnership of the Hawai'i Division of Aquatic Resources (DAR), NOAA Fisheries, Pacific Islands Regional Office (PIRO), and NOAA Ocean Service, Pacific Services Center (PSC). This is a project of the Hawaii Coral Program's Local Action Strategies (LAS), with funding from the NOAA Coral Reef Conservation Program (CRCP).

WHAT IS THE PROJECT AREA?

The Coastal Use Mapping Project will document human coastal and marine uses in the area extending from the Honolulu watershed to the Wahikuli watershed and from coast to the state jurisdictional boundary of three nautical miles out to sea. This region is a priority site for the Hawaii Coral Reef Strategy (HCRS)[†] as well as for the West Maui Watershed Project, managed by the U.S. Army Corp of Engineers.

[†] <http://coralreef.noaa.gov/aboutcrp/strategy/reprioritization/managementpriorities/>



WHAT ARE THE OUTPUTS AND OUTCOMES OF THE PROJECT?

The Coastal Use Mapping Project will produce the following outputs between August 2010 and December 2011:

- **Regional Maps of Coastal and Nearshore Ocean Uses** - Drawing upon the experience and knowledge of regional resource users, knowledgeable local stakeholders, and experts in coastal use and management on the island of Maui, the project will develop comprehensive maps, GIS data layers, and analytical products reflecting the variety and extent of ocean uses in the region.
- **Interactive Digital Mapping Tool for Local Stakeholders and Natural Resource Management Agencies** - Once GIS layers are created, they will be assembled into a digital tool that will allow users to select for use-types of interest within the project region. Stakeholders will be able to understand the extent of use-types, how they relate to each other, and how they relate to other types of information (e.g. mooring sites, zoned areas, and populated places).

HOW WILL THE PRODUCTS BE DISSEMINATED AND USED?

The Project is designed to inform ongoing management and policy decisions among federal and state agencies responsible for nearshore coral reef ecosystems in Hawai'i, with a focus on the Hawaii Coral Reef Conservation Program's priority management sites. The information will be made available to local stakeholders, community groups, and NGOs to help facilitate local natural resource stewardship efforts. Data and products will be made available via various publicly accessible websites. The results for the Hawai'i Island Coastal Mapping Project (recently conducted at the Kawaihae – Keahole priority site) can be accessed at: http://www.mpa.gov/dataanalysis/hi_coastal_use/.

CONTACTS

Arielle Levine

Regional Social Scientist
NOAA Fisheries PIRO
Arielle.Levine@noaa.gov

Petra MacGowan

Planner
Division of Aquatic Resources
Petra.MacGowan@hawaii.gov

Jamie Carter

Physical Scientist
NOAA Pacific Services Center
Jamie.Carter@noaa.gov

Characterization of dead zones and population demography of *Porites compressa* along a gradient of anthropogenic nutrient input at Kahekili Beach Park, Maui



Background

Coral reefs around Maui Island have experienced rapid and severe declines in coral cover over the past 10-15 years (Williams et al. 2008). A 2009- 2010 Maui Wide Study investigating colony scale dynamics showed that patterns and causes of coral decline are site specific. “Dead zones” or areas of nearly 100% mortality of the coral *Porites compressa* (Fig 1) have been observed at Kahekili Beach Park Maui, one of the degraded sites from the previous study. The site has a history of macro-algal blooms (Smith et al. 2005) and input of nutrient rich water via injection wells located at the Lahaina Wastewater Treatment facility just North of the site (Dailer et al. 2010). The goal of this study was to map the distribution of areas of low, intermediate and high levels of degradation and to monitor colonies to determine whether mortality is ongoing and if so to identify potential causes of mortality. Information on processes causing declines in coral coverage will allow more effective management to prevent, slow or reverse declines.

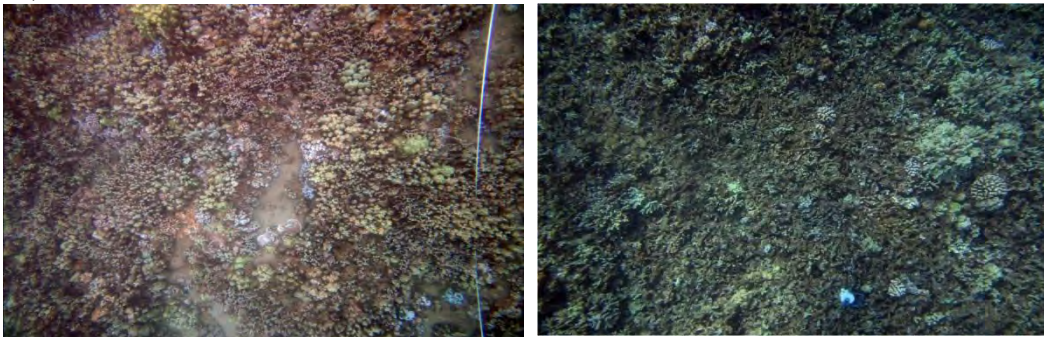


Figure 1. An area of normal coral coverage (left) and an example of a “dead zone” (right) characterized by lower coral coverage, fewer larger colonies, and higher coverage of *P. compressa* rubble and skeleton.

Methods

- Visual estimates of the amount of coral, coral rubble and skeleton and algae were recorded for each contiguous 5x5m² cell along the length of the reef (Fig 3).
- Surveys were conducted in June 2011 to quantify coral community size frequency distribution and environmental variables such as sediment composition, pH, salinity, temperature, wave action, coral disease, algal competition, and benthic coverage.
- Ten colonies each of the corals *P. lobata* and *P. compressa* were marked along each transect. Colonies were revisited and observed for signs of mortality, defined as loss of coral tissue, and causes of mortality every 1.5 months for a period of 6 months (Fig 2).

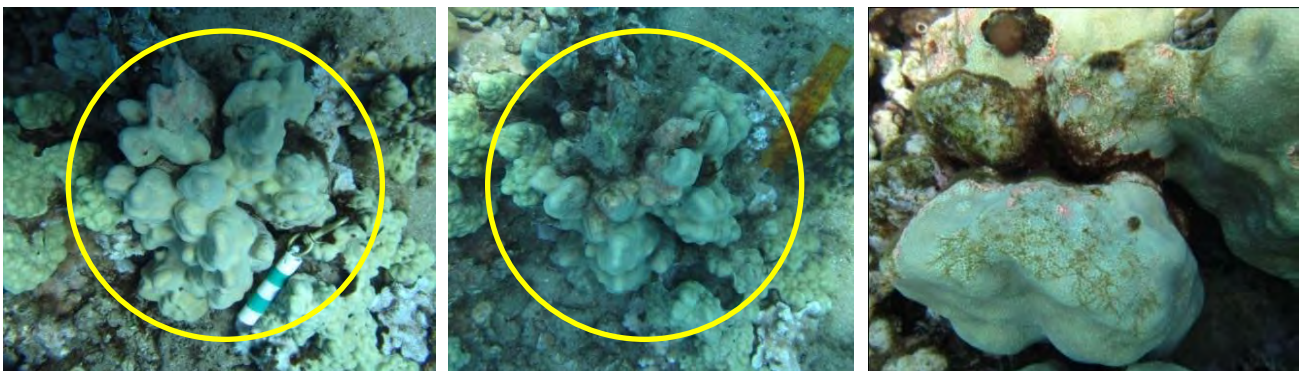


Figure 2. A *Porites lobata* colony in August 2011 (left) lost ~25% of its surface area by November 2011 (center). Tissue loss was associated with turf algal competition (right).

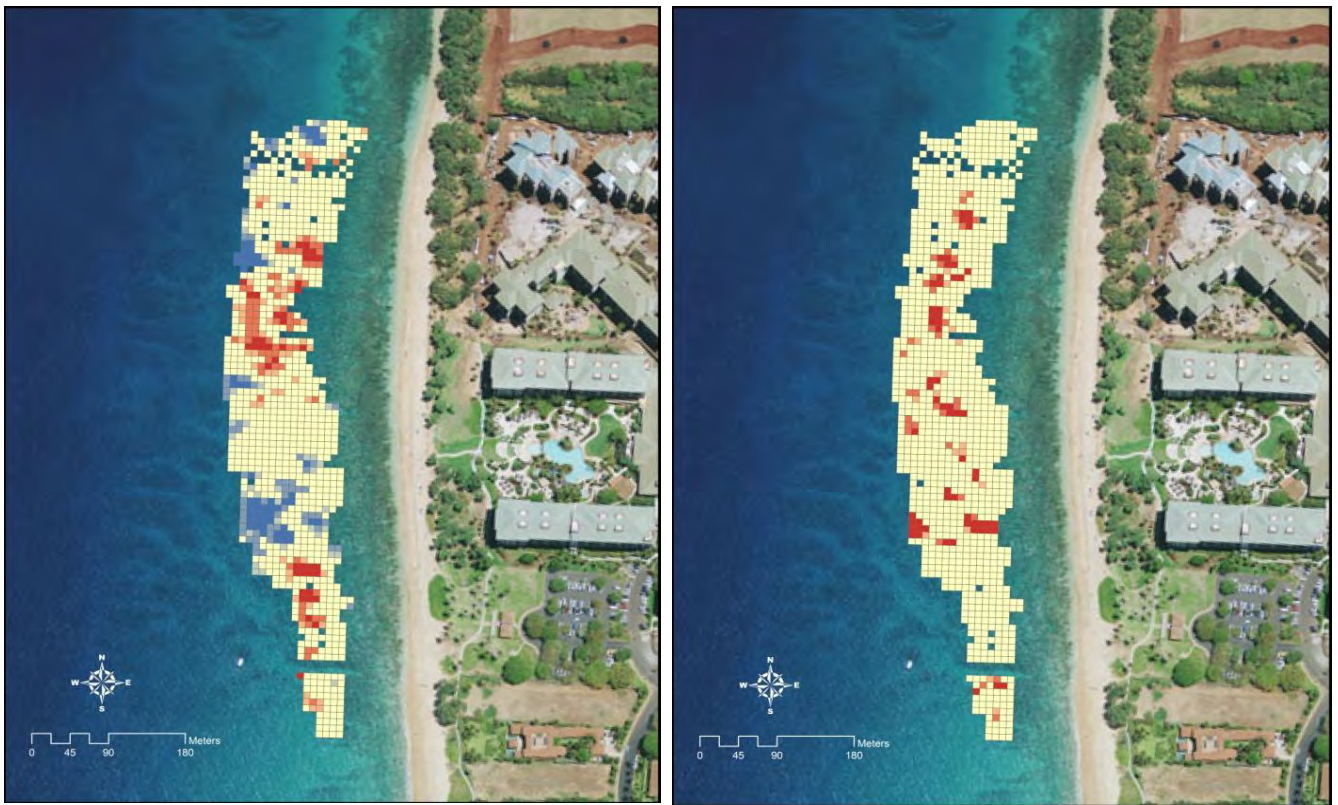


Figure 3. Maps of 5x5m² cells color coded by high (red) and low (blue) values of coral coverage (left), and high (red) values of *P. compressa* rubble coverage (right).

Conclusions

Spatial analysis of mapped cells (Fig 3) showed two types of “dead zones” along the reef at Kahekili Beach Park in North Kaanapali, Maui. The first type is characterized by low coral coverage (Fig 3 left), and moderate degradation covering relatively large areas. The second type of degradation is characterized by high *P. compressa* rubble coverage (Fig 3 right), and is severely degraded but occurs in smaller areas approximately 4-10m in maximum diameter. The recovery of these degraded areas does not appear to be limited by recruitment availability, but may be limited by survival of recruits in loose rubble.

Results based on observations of colonies over time (Fig 2) and surveys of environmental variables suggest that turf algal competition and overgrowth of live coral is an important factor in the mortality of coral in addition to macro-algal competition via seasonal and ephemeral blooms in 2001 and 2003. Results of spatial analyses show that there are more incidents of coral mortality and turf algal competition as you move North along the reef and closer to the source of effluent input. These findings provide us with a baseline of the distribution of degradation at Kahekili Beach Park as well as data related to the potential causes of mortality driving patterns of degradation.

Future Research

Continued observations of marked colonies will be made to obtain a full year of data on rates of mortality. These data are particularly important given the temporal/seasonal variation in rates and causes of mortality. Comprehensive water quality testing on finer spatial and temporal scales should be conducted. The findings from this study including the location, severity of degradation and rates of coral mortality can be used to guide these testing efforts. Analysis of long-term monitoring photoquadrats along CRAMP transect affected by “dead zone” should be conducted in order to determine whether origins of “dead zones” was chronic or catastrophic.

References

- Dailer et al. 2010. Using $\delta^{15}\text{N}$ values in algal tissue to map locations and potential sources of anthropogenic nutrient inputs on the island of Maui, Hawaii, USA. *Marine Pollution Bulletin* 60(5): 655-671.
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- Smith et al. 2005. Characterization of a large-scale ephemeral bloom of the green alga *Cladophora sericea* on the coral reefs of West Maui, Hawaii. *Marine Ecology Progress Series* 302: 77-91.
- Williams et al. 2008. Status of Maui's coral reefs. Hawaii Division of Aquatic Resources Information Sheet. <http://hawaii.gov/dlnr/dar/pus/MauiReefDeclines.pdf>

South Kohala Priority Area Projects



South Kohala Coastal Partnership

The vision:

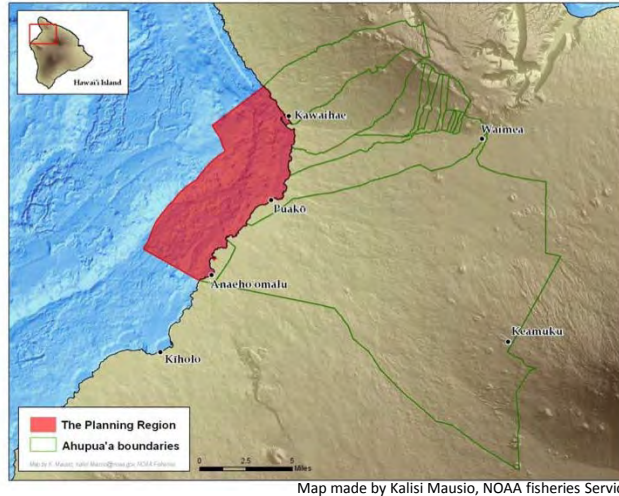
A restored, healthy, abundant, and resilient South Kohala coastal ecosystem cared for and cherished by an island community guided by the values and traditions of South Kohala.

Project area:

South Kohala District, Island of Hawaii

The State's Hawaii Coral Reef Strategy identified coral reef ecosystems along the South Kohala District coastline as a priority management site.

The area of focus includes the marine and coastal habitats along 24 - miles from the north boundary of Kawaihae ahupua'a to the south end of 'Anaeho'omalu Bay.



Progress & planning:

Since 2010 over 70 participants comprised of stakeholders and local experts from over 30 agencies and organizations contributed to the development of the South Kohala - Conservation Action Plan (CAP). The planning process includes ridge-to-reef management strategies, recognizing that the lands in the 15 ahupua'a located upland of the site are ecologically and culturally connected to the coastal waters, and in turn, that the coral reef protects the shoreline. The priority conservation targets and strategies have been identified and the implementation stage is the next phase of the process.

Conservation targets:

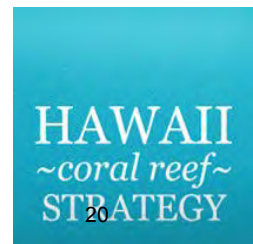
- Coastal and Marine Food Resources
- Coastal Wetlands
- Community Kinship and Stewardship
- Coral Reef Ecosystems
- Native Reef Herbivores
- Native Reef Predators

Conservation Strategies:

- Community Partnerships
- Community Co-managed Areas
- Fisheries Management
- Sediment Reduction
- Invasive Species Removal & Prevention
- Additional threat analysis

Contact:

Sierra Tobiason
tobiason@hawaii.edu
www.southkohalacoastalpartnership.com
www.hawaiicoralreefstrategy.com
www.facebook.com/SouthKohalaCoastalPartnership



Project title	Organization	Project Contacts	Location	Strategies of SKCAP	Identified outcomes
Stream Corridor Assessment	Sustainable Resource Group International	Kristin Duin, Andy Hood	Wai'ula'ula watershed	Sediment Reduction	1. Inventory and Assessment-map 2. Erosion monitoring - plan 3. Riparian zone overlays - GIS maps 4. Report - photo document, erosion plan, prioritize action
Ungulate exclusion and sediment reduction	Kailapa Community Association	Diane Kanealii	Kailapa, Kawaihae	Sediment Reduction	1. Reduce feral goat population 2. Decrease erosion and coastal sedimentation 3. Install and monitor Erosion pins 4. Establish native dry forest seed bank 5. Outreach and publications
Understanding the impacts of land based nutrients on coral reef health	The Nature Conservancy	Eric Conklin, Courtney Couch	Puako and Mauna Lani area	Fisheries Management	1. Identify sites for targeted management along the Puakō- Mauna Lani reef system 2. Test the relationship between coral health and exposure to terrestrial input), generate high resolution (spatial and temporal) temperature and salinity maps of submarine groundwater discharge (SGD) plumes to better track terrestrial input and inform future studies.
Assessment of coral settlement distributions and environmental conditions	UHM HIMB	Drs. Paul Jokiel, Ku'ulei Rodgers, Yuko Stender	South Kohala Priority site	Fisheries Management	1. Evaluation of past, present and future condition of the reef in Pelekane Bay 2. Document changes in the watershed using sedimentation data, historical data, water quality data 3. Continue monitoring and quantify coral settlement 4. Fish and benthic transects 5. Quantify water quality
Integrating Local Ecological Knowledge with a novel scientific tool to refine traditional community based Moon Calendars	UHM	Dr. Friedlander, Eva Schemmel	Kiholo Bay, and Priority Site	Fisheries Management	1. Identify local pono fishing practices, 2. life history and histological data, 3. Spatial and temporal variation in reproductive characteristics, 4. training and technical support to communities
Implementation of South Kohala Conservation Action Plan	UH Sea Grant	Darren Lerner, Sierra Tobiason	South Kohala Priority site	All	Coordinate and staff a locally based working group, 2. Organize and lead local stakeholder engagement related to Phase I implementation of South Kohala Projects, 3. Review and synthesize reports, research materials and study findings to communicate information, 4. Assist with project oversight.



Implementation of South Kohala Conservation Action Plan

2014

PROJECT OVERVIEW

The coral reef ecosystems of South Kohala, Hawaii Island have been identified as a high priority management site for the Hawaii Coral Reef Strategy. The major threats identified in this area include:

- Land based sources of pollution,
- Invasive species and,
- Unsustainable fishing practices.

Through the guidance and collaboration of community members, organizations, resource managers as well as State and Federal agencies in the region, the South Kohala Conservation Action Plan (SKCAP) was developed and the South Kohala Coastal Partnership was formed. The strategies include Community partnerships, Community Co-managed Areas, Fisheries Management, Sediment Reduction, Invasive Species, and Additional threat analysis. There are also two watershed management plans: Wai'ula'ula Watershed Management Plan and Pelekane Bay Watershed Management Plan that include strategies for the South Kohala area.

The management strategies in this area include a ridge to reef approach, recognizing that the lands in the 15 ahupua'a located upland of the coral reef ecosystems site are ecologically and culturally connected to the coastal waters.

APPROACH

Through a partnership established between Hawai'i Division of Aquatic Resources (DAR) and the University of Hawai'i Sea Grant College Program (UH Sea Grant), an extension agent position was established to serve as the project coordinator. Ms. Sierra Tobiason was hired on July 1, 2013 and is responsible for coordinating activities associated with the implementation of the South Kohala Conservation Action Plan.

The South Kohala Coastal Partnership was able to implement five projects with the support from NOAA's Coral Reef Conservation Program under awards #NA11NOS4820006 and #NA13NOS4820014 to DAR.

MOST IMPORTANT RESULTS

- *South Kohala Coastal Partnership participation and support from over 100 organizations and agencies and 215 participants*
- *6 coastal communities actively engaged in organized ecosystem based stewardship activities*
- *58 monitoring stations established*

SITE LOCATION



South Kohala Coastal Partnership Projects: 7/1/13-9/30/14

- Ungulate Exclusion and Sediment Reduction - Kailapa Community Association
- Coral Health and Land Based Sources of Pollution - The Nature Conservancy
- Stream Corridor Assessment - Sustainable Resources Group International Inc. (SRGII)
- Community Based Fishing Moon Calendar - UH Manoa
- Coral Settlement and Environmental Conditions - HIMB



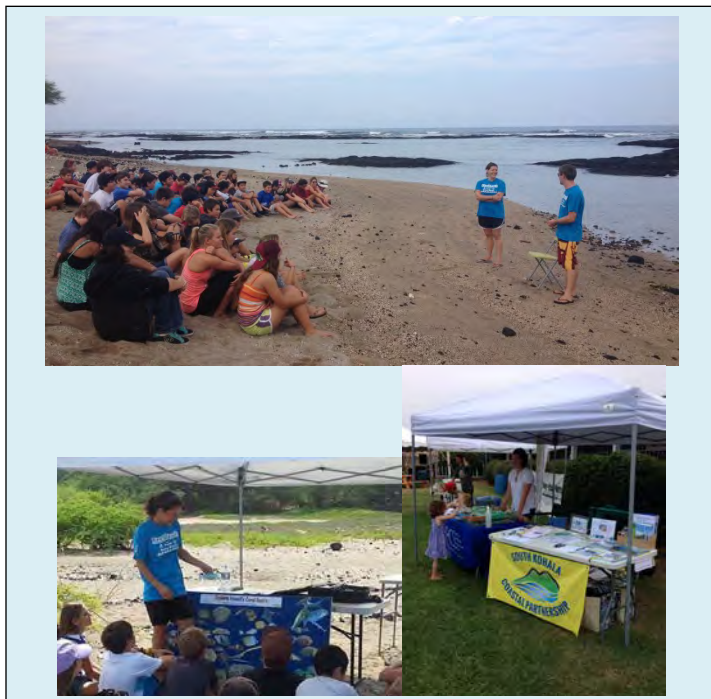
The South Kohala Coastal Partnership is a dynamic partnership committed to the implementation of the SKCAP guided by the shared vision. The vision of the South Kohala Coastal Partnership is to achieve: A restored, healthy, abundant and resilient South Kohala coastal system cared for and cherished by an island community guided by the values and traditions of South Kohala.

HAWAII
~coral reef~
STRATEGY

ACCOMPLISHMENTS

The projects contributed to:

- 13 acres fenced off to exclude invasive ungulates (goats), one sediment check dam was built and over 1,200 native dry land forest species planted with the Kailapa community in Kawaihae to reduce sediment runoff.
- 12 monitoring sites were established to track coral health and nutrients in Puakō with The Nature Conservancy team
- 8 monitoring sites along the Wai'ula'ula watershed installed by SRGII and as a result 5 of those sites were selected for the Wai'ula'ula watershed implementation funding from the Department of Health Clean Water Branch.
- Over 480 samples from 38 reef fishes collected by West Hawaii fishermen for the Hawaiian Fishing Moon Calendar.
- 38 coral recruitment monitoring stations installed
- A total of 6 coastal communities actively engaged in organized ecosystem based stewardship activities.
- Over 3,392 residents and visitors reached and informed about these projects and coastal and marine management efforts through participation in meetings, education and outreach events and communication plan strategies.



South Kohala Coastal Partnership Education & Outreach Top & bottom left: Puakō Reef Teach lesson with students, Bottom right: NRCS and Mauna Kea Soil and Water Conservation District watershed activities.

MANAGEMENT IMPLICATIONS

Over the course of this project the coordinator worked with partners to identify and develop additional projects and facilitate the establishment of new collaborations. The coordinator was able to utilize the data from these projects to leverage and secure funding for two additional projects. A \$15,000 NOAA PIRO Fisheries Marine Education and Training grant for the development of a "Coastal Community Monitoring Tool Kit (C-Water Kit)" includes water quality monitoring, training and educational programs for both coastal communities and students. Also awarded was a \$427,218 grant from the Hawai'i Department of Health (DOH) Clean Water Branch for the "Implementation of Best Management Practices to reduce non-point source pollution and storm water runoff in Wai'ula'ula Watershed."

The results and recommended management actions, to reduce land based sources of pollution will available on the website to help inform and prioritize future management efforts.

The South Kohala Coastal Partnership working group is composed of representatives from The Nature Conservancy (TNC), UH Sea Grant, United States Department of Agriculture - Natural Resource Conservation Service (NRCS), National Oceanographic and Atmospheric Administration (NOAA), Hawaiian Island Humpback Whale National Marine Sanctuary, National Park Service, Ala Kahakai National Historic Trail, Mauna Kea Soil and Water Conservation District, Hawai'i Department of Land and Natural Resources, and Division of Aquatic Resources (DAR).



South Kohala Coastal Partnership working group and project managers

More Information

Sierra Tobiason
 tobiason@hawaii.edu
www.southkhalacoastalpartnership.com
www.hawaiicoralreefstrategy.com
www.facebook.com/SouthKohalaCoastalPartnership

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 STRATEGY

PROJECT OVERVIEW

The South Kohala Conservation Action Plan (SKCAP) presents strategies to address threats to the coral reef ecosystems along 24 miles of marine and coastal habitats from Kawaihae to 'Anaeho'omalu Bay. This is a high priority management area of the Hawai'i Coral Reef Working Group.

A Stream Corridor Assessment (SCA) was conducted in Wai'ula'ula Watershed to document the location, extent, and cause of sediment, nutrient, and toxicant-load contributions from erosion along the various channels of the stream and gulches, and adjacent lands. A SCA is a tool that can help identify specific stream and riparian areas that require restoration, and help prioritize critical areas. Identifying management actions to reduce erosion and stabilize erosion-prone streambanks will facilitate implementation of projects aimed at reducing delivery of sediment and associated pollutants to coral reefs.

The SCA is part of a larger group of projects in the South Kohala region aimed at increasing stakeholder awareness and understanding of erosion and ways to reduce sediment delivery to reefs.

PROJECT GOALS AND OBJECTIVES

Goal: Identify areas to target for installation of management practices to decrease erosion rates to reduce stress on nearshore waters and coral reefs.

Objective 1: Assess the condition of eroding streambanks in the agriculture, rural, and urban zones of Wai'ula'ula Watershed.

Objective 2: Identify sites for installation and assignment of practice types for issues to be remediated.

Objective 3: Create erosion monitoring plan.

Objective 4: Install erosion pins and monitor sites.

Objective 5: Propose riparian zone overlays for consideration by Hawaii County.

Objective 6: Prioritize management actions for streambank stabilization and restoration based on field work and erosion monitoring.

Objective 7: Increase stakeholder's awareness and understanding of erosion and reducing sediment delivery to reefs.

RESULTS

- *Stream reaches in Wai'ula'ula Watershed are geologically young, making it challenging to discern between instability due to natural channel forming processes and human impacts.*
- *Agricultural (grazing and crops) and urban land uses have an impact on the surface and ground water hydrology, including the timing and magnitude of surface runoff from storm events, its quality, and resulting land based pollutants.*
- *Thirty-one specific sites were identified as targets for remediation and prioritized for action: 18 low, 9 medium, and 4 high. Five already funded.*
- *A set of watershed management practices to address erosion control and water quality was identified.*



Sites with bare ground and erosion targeted for remediation

MANAGEMENT OUTCOMES

Next steps:

- Implement suggested remedial actions and best management practices.
- Continue erosion monitoring to assess effectiveness.
- Demonstrate links between installation of best management practices and improvements in stream and coastal water quality.
- Implement policy changes to provide for riparian and stream corridor buffers in agricultural & urban areas.

Understanding the consequences of land-based pollutants on coral health in South Kohala

Drs. Courtney Couch and Eric Conklin
November 5, 2014

PROJECT OVERVIEW

The Puakō-Mauna Lani reef system is one of the most well-developed fringing reefs on the Island of Hawai'i, providing countless ecological, economic and cultural resources to Hawai'i. During the last 50 years, Puakō has experienced substantial changes in overall reef health, with a 50% decline in coral cover since the 1970's. While the causes of this decline are poorly understood, land-based pollution (LBP) is thought to be a major contributor to the degradation of coral health. LBP is of particular concern along the Puakō-Mauna Lani coastline of South Kohala due to extensive land use change, high recreational use, ineffective sewage treatment and vulnerability to pollution due to its highly porous rock and high volume of underground freshwater discharge, which can deliver LBP to near shore reefs. This project seeks to understand the impacts of land-based pollution on coral reef health, a priority strategy identified by community members and other stakeholders in the South Kohala Conservation Action Plan.

PROJECT GOALS AND OBJECTIVES

To better understand the contribution of land based pollution (LBP) to overall coral health and address a priority management issue we:

- (1) Surveyed the coral, algal and reef fish communities at 37 sites throughout the Puakō-Mauna Lani reef to determine broad patterns in coral reef health.
- (2) Identified 12 sites across a range of LBP input and characterized water quality (temperature, salinity, nutrients, and proxies of productivity and sewage contamination) across these sites.
- (3) Characterized spatial patterns in coral disease and compromised coral health and determined whether these patterns were correlated with water quality parameters.
- (4) Prioritized regions for with impaired water quality and degraded coral health for corrective action.

RESULTS

- We identified four areas for targeted management action: the reef between sites 4 and 6, Pau'oa Bay/Mauna Lani (near 13 and 14), the reef between sites 2 and 3 and Paniau (Fig. 1).
- The abundance of *Enterococcus*, an indicator of human sewage, was 7 times higher in shoreline waters compared to reef waters and exceeded the EPA standard for marine waters at 75% of shoreline sites.
- Enterococci abundance was higher in freshwater flows, suggesting that freshwater coming from land may serve as one delivery mechanism of LBP.
- Overall, 24% of corals were diseased and 27% showed signs of compromised health (algal overgrowth, discoloration, physical damage and bleaching), with degraded coral health primarily driven by skeletal deformities and overgrowth by algae.
- Elevated nutrient concentration was the strongest predictor of disease, with more skeletal deformities on reefs with higher nutrient levels (i.e., elevated silica and nitrate + nitrate concentration).

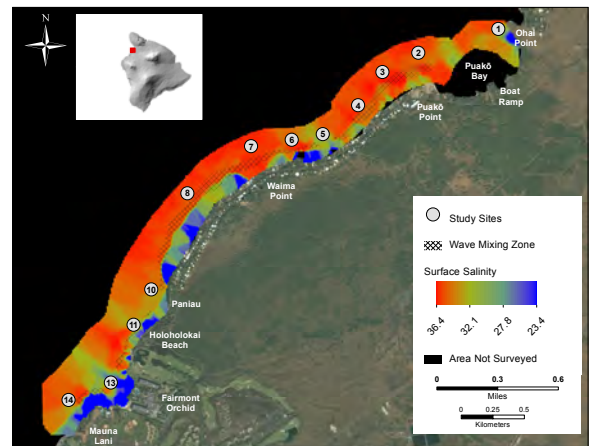


Figure 1. Map showing underground freshwater discharge onto study reefs in December 2013, and the 12 coral health and water quality study sites.

MANAGEMENT OUTCOMES

This study shows that exposure to groundwater may be linked with impaired coral health, and identifies sites that would most benefit from management actions to improve water quality. In light of interest within the Puakō community to improve sewage treatment, additional focus should be devoted to addressing LBP and coral health at the 4 target areas (see Results). Future efforts should also focus on reducing nutrient pollution across the watershed, establishing the causal link between nutrients and coral health, and addressing other pollutants (e.g. chemicals) that may be flowing onto reefs and degrading coral health.

PROJECT OVERVIEW

Hawaii's watersheds have been under significant threat from ungulate introduction, changes in land use, invasive species and other anthropogenic impacts. Native plant species found in dryland forests used to be present in Kawaihae but due to these impacts such as feral ungulates (goats) damaging the watershed there is very little left of these forests. This project led by the Kailapa Community is working to replant native species previously found in the area to help improve the health of watershed of Kawaihae and reduce sediment runoff from entering the coastal and marine ecosystems. The goal of this project was to reduce local erosion and its effects with ungulate-proof fencing and propagating and out-planting native plants.

Objectives of the project included taking action to:

- Decrease erosion and sediment runoff,
- Establish native plants to stabilize soil,
- Educate the broad community on watershed management strategies,
- Provide outreach to future leaders of our islands,
- Protect the watershed,
- Establish monitoring plan and collect baseline data on water quality,
- Strengthening partnerships with other organizations with similar visions and goals.

APPROACH

To achieve our goals we conducted the following activities:

- Designed, installed and maintained an ungulate proof fencing and exclusion area of 13 acres,
- Planted over 1,200 native plants and established a dry-land forest seed bank,
- Presented information at outreach events and community meetings,
- Organized community work days and workshops with local watershed experts,
- Installed a variety of soil retention methods (native re-vegetation and sediment dam),

MOST IMPORTANT RESULTS

- 15 community work days with 198 volunteers,
- Fenced approximately 13 acres of land with ungulate (goat) proof fencing,
- One large sediment dam built and multiple smaller dams installed,
- Over 1,200 native plants propagated and out planted.

SITE LOCATION



- Collected baseline data on erosion rates and water quality,
- Engaged and educated residents of Kohala and community members about watershed management and land use practices that minimize sediment runoff with the guidance of the South Kohala Coastal Partnership.



www.kailapa.org

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ACCOMPLISHMENTS

The 13 acre project area was fenced in order to re-vegetate native plants and reduce sediment runoff into the adjacent coastal and marine ecosystems. Over 1,200 native plants were propagated and out-planted with an 80% survival rate. The irrigation lines were installed and prepared for the next out-planting of an additional 1,300 plants. One large sediment check dam was built and several small rock dams were strategically placed to capture and reduce sediment runoff. Community members were trained to repair the irrigation lines, monitor the plants and to maintain the ungulate fence.

Over 198 volunteers participated in community work days and workshops with over 15 organizations providing expertise and support for the project.

The community established new partnerships with Liquid Robotics to collect and analyze baseline water quality samples offshore and the UH Hilo Marine Science Analytic Lab to analyze the near shore water samples to document the effectiveness of the sediment reduction efforts.



Figures 1a and b: Sediment check dams and native plants were installed to capture and reduce sediment entering the ocean.

MANAGEMENT IMPLICATIONS

This project addressed the South Kohala Conservation Action Plan Objective 1: Community Partnerships, and Objective 4: Sediment Reduction.

The project has engaged not just members of Kailapa but a broad range of volunteers who participated in our organization's efforts. The efforts highlighted the fact that whatever is done on land will affect what happens in the ocean. Community awareness of the importance of watershed and resource management was improved not just for Kailapa, but all participants, partners, and volunteers. The project emphasized our social responsibilities and the positive effects of small changes we can make.

The project serves as an example of a successful community led partnership project that effectively implemented multiple strategies to reduce impacts to the coastal and marine ecosystems while increasing community engagement and awareness of watershed restoration.

To highlight the ungulate fencing and sediment reduction project and methods site visits were conducted with representatives from state and federal agencies as well as local youth groups and

the University of Hawaii at Hilo students and faculty.

This site will continue to serve as a location for site visits with stakeholder groups interested in the application of these management strategies in other locations or communities. Additionally, educational service learning opportunities and coastal monitoring will continue to provide an increase understanding of watershed management and reducing impacts to coastal and marine ecosystems.



Figure 2: Coastline near project site, note the exposed soil and sediment in the water

More Information

Sierra Tobiason

tobiason@hawaii.edu

www.southkohalacoastalpartnership.com

www.hawaiicoralreefstrategy.com

www.facebook.com/SouthKohalaCoastalPartnership

HAWAII
~coral reef~
STRATEGY

PROJECT OVERVIEW

Ancient Hawaiians understood the lunar rhythms and seasonal patterns of important resource species and created moon calendars to inform the wise management of those resources. These moon calendars were used to predict seasonal, monthly, and daily ecological cycles of harvested species. This information was used to dictate proper harvest seasons and strategies and identify “kapu” or no-take periods on harvest during critical periods of development and reproduction.

Traditional knowledge tells us that seasonal cycles are unique to each island region. Fish spawning seasons still need to be determined for each bay or region to fully understand local resources.

Through collaborations between local communities, scientists, and management agencies, we are creating moon calendars with communities around the state to share local spawning seasons and pono (sustainable) harvest practices. Our project goals:

1. Raise awareness of traditional pono fishing practices to improve the health of fish stocks.
2. Identify spawning times for fishery resource species, focusing on Kala, Kole, Manini, Akule, and others.
3. Develop fishing moon calendars.

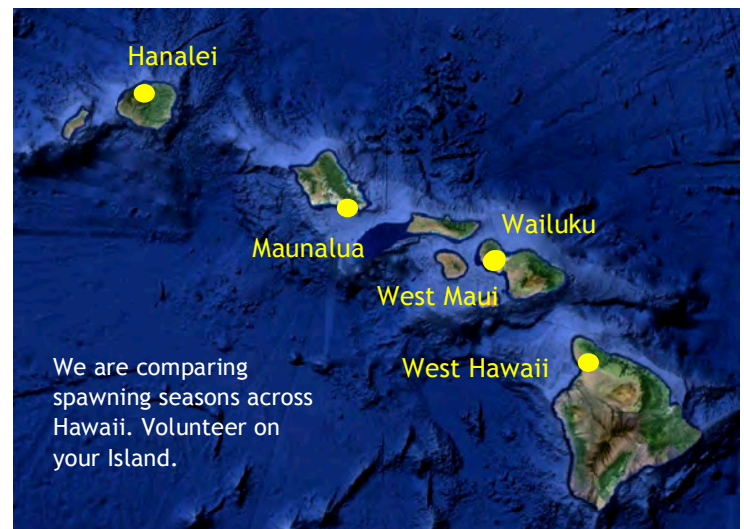
APPROACH

- Local fishermen are trained to observe gonad (egg) development in fish and drop off gonad samples for scientific analysis.
- UH Scientists analyze the gonad samples to determine time of spawning and size of maturity (size that fish are capable of spawning). This information is used to inform the appropriate harvest size and harvest times.
- Partners: Local communities, Conservational International’s Hawaii Fish Trust, UH Manoa, NOAA Papahānaumokuākea, NOAA Hawaii Islands Humpback Whale National Marine Sanctuary, Sea Grant, and Hawaii DAR.

MOST IMPORTANT RESULTS

- Identifying pono (sustainable) harvest practices.
- Providing education opportunities and community training in fish spawning seasons and sustainable harvest practices.
- Linking community values with local management goals.

SITE LOCATIONS



To volunteer contact:

Eva Schemmel
Fisheries Ecology Research Lab
University of Hawaii, Manoa
spawningseasons@gmail.com
www.facebook.com/spawningseasons
Phone: 808-956-8350



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HAWAII
~coral reef~
STRATEGY

ACCOMPLISHMENTS

We have been working towards sustainable harvest in South Kohala by learning the natural cycles of our resources and knowing the proper times to harvest.

- *Outreach and training on sustainable fishing practices are held regularly in South Kohala. Please check the www.facebook.com/spawningseasons for upcoming events.*
- *We are working with fishermen in the area to identify spawning seasons and size that fish begin to spawn for several important reef fishes.*
- *We have found that the size that fish reach adulthood and are capable of spawning is different by island regions.*
- *Our research suggests that spawning seasons are variable and influenced by location.*



Manini (convict tang) eggs during spawning. Scientific assessment allows provides detailed picture of the eggs.

MANAGEMENT IMPLICATIONS

This project is increasing community-based resource management and conservation in the Hawaiian Islands by identifying local pono fishing practices and combining this traditional knowledge with scientific techniques.

Communities are using this information to develop local resource monitoring programs and increasing resource users' influence on the local management. South Kohala is just one location where spawning season research is occurring. We are comparing spawning seasons for reef fish from Kauai, Oahu, Maui, and Hawaii Island to understand the variability in spawning seasons and size that fish become spawning capable.

Through this research we will identify local strategies to increase future resource abundance. These will be specific to each location, but some important management measures are common to all locations:

- *Limit harvest during spawning seasons.*
- *Leave larger sized fish.*
- *Harvest only what you need.*

To ensure that our resources persist into the future we must monitor the natural cycles of our resources and share this knowledge among resource users.



Community training on fish spawning seasons and pono fishing practices.

More Information

Sierra Tobiason
tobiason@hawaii.edu
www.southkohalacoastalpartnership.com
www.hawaiicoralreefstrategy.com
www.facebook.com/SouthKohalaCoastalPartnership

Dr. Paul Jokiel, February 9, 2015

Pelekane Bay has been severely impacted by the construction of the neighboring Kawaihae Harbor in the 1950's and subsequent changes in land use throughout the bay's watershed. Sedimentation and other forms of land-based pollution have led to declines in water quality and coral reef ecosystem health over the last two decades. The Kohala Watershed Partnership was awarded \$2.7 mill from NOAA's Restoration Center as part of the American Recovery and Reinvestment Act (ARRA) of 2009 to stabilize soil and improve land use practices on the watershed. This work has been completed and various upland watershed management activities are ongoing that will reduce land-based sources of pollution into Pelekane Bay. There is a need to determine the efficacy of land restoration and reef recovery. The emerging South Kohala Conservation Action Plan (SKCAP) has identified a number of "Target" areas that will require scientific input on the condition of the reefs.

The proposed project have used an extensive existing database coupled with additional work focusing on coral settlement patterns to address project goals and establish a framework to evaluate the success of restoration efforts.

The aim of this project is to:

- (1) evaluate the effectiveness of the terrestrial watershed remediation efforts in relationship to reef recovery,**
- (2) understand the potential of the local marine ecosystem to recover by evaluating the distribution of coral settlement and recruitment as the indicators along environmental regimes,**
- (3) understand the potential threat that existing mud deposits pose to adjacent, relatively pristine coral reef ecosystems.**

RESULTS

- The existing and new data analyzed suggests changes in reef communities occurred in the last 30 years in Pelekane area.
- Reef fish abundance and diversity increased since 1996.
- Decline of live coral cover has stabilized since 1996 following a substantial reduction between 1976 and 1996.
- Coral settlement was substantially less inshore where is impacted by sedimentation than offshore reefs in both 2011 and 2014.
- No strong temporal variation was observed in coral settlement between years.
- Recent episodic seasonal large wave events demonstrate that natural processes remove accumulated sediment deposits on coral reefs offshore deeper water.
- Minimal threat of mud deposit to offshore reefs affecting habitat quality.

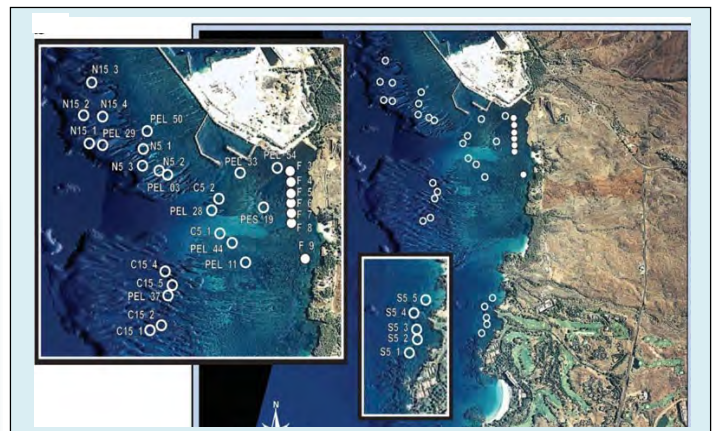


Figure 1. Coral settlement sites at 37 stations. Inset indicates settlement sites in Pelekane Bay area.

MANAGEMENT OUTCOMES

This project evaluated the changes on the reef in relation to changes on the watershed. It provides a frame work relevant to other watershed restoration efforts currently being planned in neighboring watersheds with large amount of scientific information developed through multi-organizational collaboration efforts. Continued monitoring of reef communities and expansion of the original dataset will allow evaluation of the resource while laying the foundation for future assessments of the efficacy of conservation measures.

The Hawai'i Division of Aquatic Resources has been intensively monitoring West Hawai'i reefs since 1999 in conjunction with a number of long-term studies extending over multiple decades. Over the past 16 years of monitoring, a total of 70 survey divers have conducted over 6,700 100m² transects for the West Hawai'i Aquarium Project (WHAP) in addition to hundreds of other surveys for related projects. This information is utilized to monitor the condition of the West Hawai'i's reefs and inform management decisions.

The no-aquarium collecting Fish Replenishment Areas (FRAs), implemented in 1999, have been very successful in increasing populations of Yellow Tang (*Zebrasoma flavescens*) which is the most heavily targeted aquarium fish accounting for 84% of the total catch. Fifteen years after closure, the population of Yellow Tang has increased 64.5% in the FRAs while its abundance in the Open Areas has not declined significantly.

Overall Yellow Tang abundance in the 30'-60' depth range over the entire West Hawai'i coast has increased by over 1.3 million fish from 1999/2000 to 2012-2013 to a current population of 3.6 million fish.

Two of three sites at long-term studies in South Kohala and South Kona have found Yellow Tang populations have increased to levels found over three decades ago before the expansion of aquarium collecting.

Outward movement of adult Yellow Tang from protected areas into surrounding areas ('spillover') augments adult stocks in Open Areas up to a kilometer or more away.



There are no significant differences in the abundance of adult Yellow Tang in Open vs. closed areas in shallow water (10'-20' depths). Total estimated coastwise population of adult Yellow Tang in this depth range was estimated to be >2.5 million individuals.

West Hawai'i had a significantly greater percent change in Yellow Tang density within its networked MPAs (and Open Areas) as compared to the non-networked sites on Maui. Five of the 10 most collected aquarium fish in West Hawai'i were significantly more abundant in West Hawai'i's Open Areas as compared to Maui MPA closed areas.

The FRAs have also been very successful in increasing Kole (*Ctenochaetus strigosus*) populations. This species is the second most aquarium collected species, representing 8% of the total catch. The number of Kole increased significantly in all management areas, including Open Areas, from 1999/2000 to 2012/2013. Overall Kole abundance in 30'-60' depth range over the entire West Hawai'i coast increased by over 2.1 million fish during this time period with a current population of about 6.5 million fish.

Long-term West Hawai'i studies have found Kole populations to have decreased from 31% in South Kona to 71% in South Kohala. Given the length of protection at these sites and the overall

decline in habitat quality and fish populations in South Kohala it seems unlikely that the declines are due primarily to aquarium collecting.

Comparative surveys utilizing DAR and NOAA data indicate Kole are substantially more abundant in West Hawai'i over most size ranges than in any of the other islands in the Main Hawaiian Islands or the Northwest Hawaiian Islands.

Achilles Tang (*Acanthurus achilles*) have declined in FRAs and Open Areas over the last 15 years tempered somewhat by a slight increase in the last year or two. A similar declining trend is apparent within MPAs except for the last four years when their numbers have increased. Open Area populations are higher than FRA (albeit both being low).

Achilles Tang has had low levels of recruitment over the past decade and substantial numbers of larger fish (i.e. 'breeders') are taken for human consumption.

Of the other top 10 collected aquarium species, two species (Forcepsfish – *Forcipiger flavissimus* and Potter's Angelfish – *Centropyge potteri*) increased in one or more of the management areas while two species (Ornate Wrasse – *Halichoeres ornatissimus* and Fourspot Butterflyfish – *Chaetodon quadrimaculatus*) declined. While the latter two species declined in the Open Areas, they also declined in one or the other of the protected areas (FRA or MPA) suggesting that factors other than aquarium collecting were also affecting their populations.

For 24 other species on the White List, five showed a significant population increase in one or more of the management areas while 11 decreased. Of the species which declined, only a single one (Bird Wrasse) declined exclusively in the Open Areas indicating that factors other than aquarium collecting were also affecting the populations of the other species.

For the Bird Wrasse (*Gomphosus varius*), reported annual take is so low and such a minimal percentage of the total Open Area population (< 0.5%) it's difficult to see how collecting alone could be the cause of this species' population decline in the Open Areas.

For most of the species on the White List, collecting impact, in terms of the percentage of the population being removed annually, is relatively low with 8 species having single digit percent catch and 23 species having catch values <1%.

In terms of the yearly differences in a species' abundance between the Open Areas and the FRAs 6 species have been consistently more abundant in the FRAs than in the Open Areas. Eleven species showed no consistent pattern and 17 species were consistently more abundant in the Open Areas.

Besides harvest impacts, species abundances change over time due to both extrinsic and intrinsic factors. This is exemplified by the Saddle Wrasse which underwent significant declines in all management areas since 1999/2000. This species is consistently more abundant in the Open Areas than in the FRAs or MPAs.

Six of 11 endemic species on the White List are common in suitable habitat. Collecting pressure on 8 of these species takes <9% of their Open Area population annually. Seven of the 8 species have <1% of their population collected annually.

Herbivore biomass is significantly higher (1.8X) in the West Hawai'i MPAs than in the FRAs or the Open areas, both of which are declining. Herbivore biomass is slightly but significantly greater in the FRAs than in the Open areas. Other types of fishing (i.e. food fishing) are likely responsible for observed differences between these areas and the more protected MPAs.

General State of Hawai`i Projects



Photo by Catlin Seaview Survey

The State of Hawaii Makai Watch Program

Hawaii's *Makai Watch Program* is a collaborative program where communities, non-government organizations (NGOs), and the Department of Land and Natural Resources (DLNR) work together to improve stewardship of marine and coastal resources. This innovative program is modeled after the successful Neighborhood Watch programs.

On October 10th, 2014, the Board of Land and Natural Resources officially recognized and approved the State of Hawaii Makai Watch Program. This accomplishment will allow the state Makai Watch coordinator to begin working with communities compliant with the Makai Watch requirements to pursue a Memorandum of Agreement (MOA) with the DLNR.



A media press conference was hosted by the Malama Pupukeya Waimea (MPW) Makai Watch program. MPW became the first Makai Watch program on Oahu in partnership with DOCARE and DAR. This year, MPW will celebrate the 31st anniversary of the conservation district, as the organization continues to thrive and grow with increased community support, expanded programs, a hearty volunteer network, strong partnerships, and a dedicated board and staff.

With the approval of the State Makai Watch Program, a logo was created to embrace the essence of Makai Watch. The ocean connects us to each other and our resources, and in return we malama (*care for*) our ocean. The ocean to many is a place of peace, serenity, sustenance, to others a place of recreation, and to some a way to earn a living. This logo embraces our resources (the fish) and the ocean (wave) in a symbolic infinite sign, as we will continually malama our relationship with our ocean and its resources for generation and generations to come.



'Ike Kai—Makai Watch Training Project

Goal: Increase volunteer understanding of basic marine ecology and resource management topics

- ♦ Creation of printed resource guide to support volunteer Awareness-Raising and Outreach activities
- ♦ Site-specific, interactive training module to compliment MW training in Spring 2015
- ♦ Final report detailing volunteer success June 2015

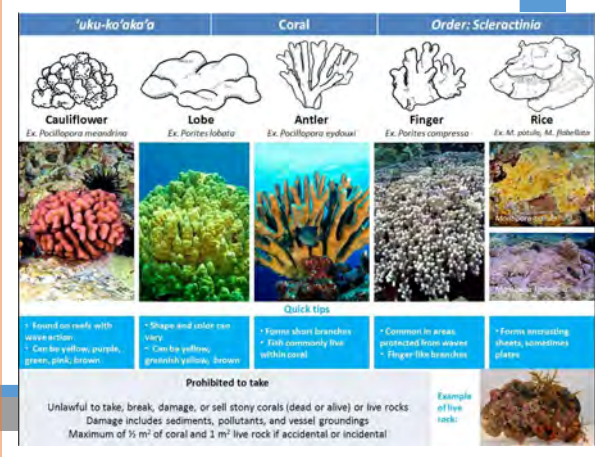
Makai Watch Volunteer Training: Part 2

Regulated Marine Life ID
and Marine Resource Management



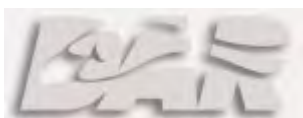
In 2014, Anne Rosinski (former NOAA CRCP Fellow and DAR Marine Resource Specialist) developed a project to train Makai Watch volunteers on basic marine ecology including visual identification of state regulated marine life as well as clarifying marine resource management concepts and state rules. This will strengthen the overall program by ensuring accurate volunteer reporting of resource violations and updating and clarifying information provided through outreach activities.

The project will be implemented in Spring 2015, providing an in-person interactive training to each of the 8 Makai Watch sites



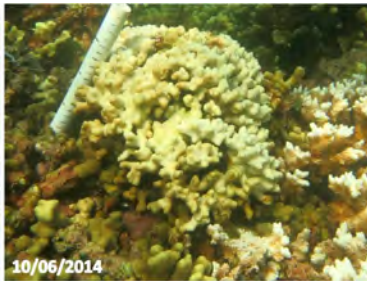
Makai Watch Funding

- ♦ Funding for State Makai Watch Coordinator Position from Conservation International Hawaii and the Harold K. Castle Foundation thru October 2015.
- ♦ The State Makai Watch Coordinator position has been submitted with the Administrative DOCARE budget to institutionalize the coordinator position within DOCARE.
- ♦ Proposal submitted to the NOAA-CRCP for final phase of the Makai Watch Strategy Implementation and Maintenance in 2016-2017.
- ♦ The 'Ike Kai training project was supported by a grant from the NOAA-NMFS Education and Training Program
- ♦ Received Hawaii Tourism Authority grant to expand the Makai Watch Volunteer training to include the Visitor Industry and Commercial Operators near or within the Makai Watch program areas.

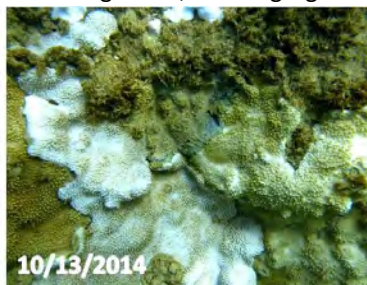


The Reef Response Program

Assessing damaging coral reef events including coral disease, bleaching, Crown Of Thorns Starfish (COTS), and Aquatic Invasive Species (AIS)



Coral in Kaneohe Bay, Oahu during (left) and after (right) the bleaching event, showing signs of recovery, photo: DAR



Coral in at Anahola, Kauai during (left) and after (right) the bleaching event, showing signs of recovery, photo: DAR

Hawaii Coral Bleaching Event

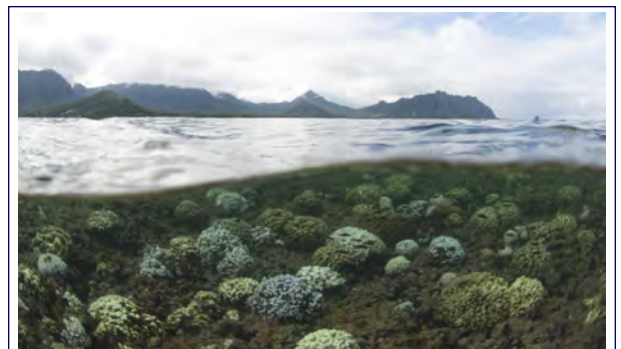
- In Oct, 2014 Hawaii experienced a period of extreme temperatures peaking at 86F, triggering a coral bleaching event statewide
- Certain areas of Kauai, Oahu, and Maui were affected more severely, especially Kaneohe Bay where 70-80% of the dominant corals were bleaching
- DAR coordinated a response group that deployed a Rapid Response Team to survey the extent and severity of this event including tagging over 50 colonies in Kaneohe Bay to monitor for signs of Recovery
- In January 2015, the Rapid Response Team began to see corals throughout the state re-coloring
- In February 2015, a severe coral disease outbreak was discovered and continues to negatively affect corals



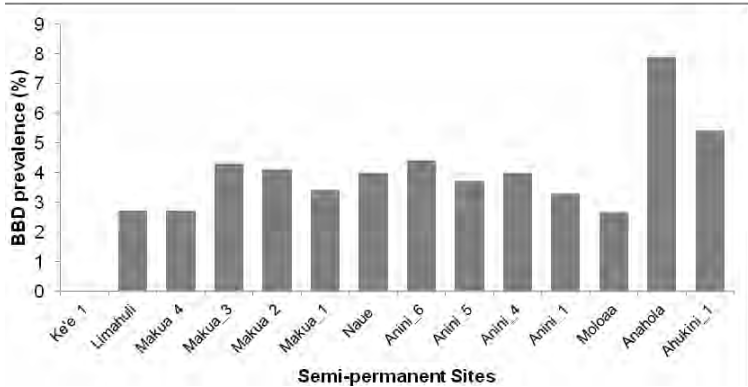
(above) The DAR Rapid Response Team surveying bleached coral in Kaneohe Bay, Oahu in October 2014 captured by 360° imagery by the Catlin Seaview Survey Projectt below) Kaneohe Bay, Oahu in October 2014, photos: Catlin Seaview Survey

Next Steps:

- Continue monitoring corals affected by 2014 bleaching
- Prepare for 2015 bleaching season, which is predicted to be more severe than in 2014
- Quantify mortality following Kaneohe Bay coral disease outbreak
- Revise bleaching monitoring protocols based on lessons learned in 2014
- Continue working with the Eyes of the Reef Network to catalog community reports and observations

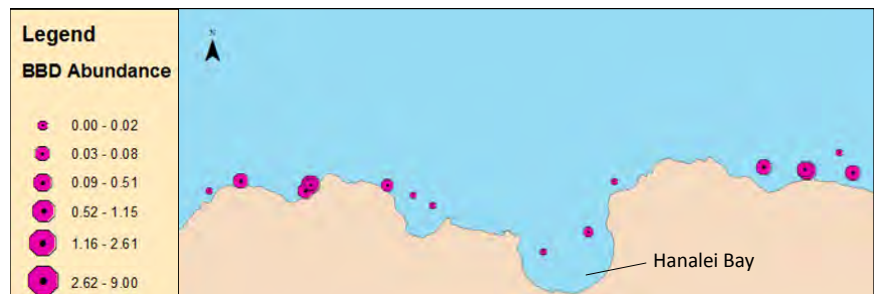


Kauai Coral Disease Update



(above) BBD prevalence on the north shore of Kauai, showing disease hotspots.
All data and graphs courtesy of C. Runyon (UH)

- In January 2014, DAR formed a Management Response Team to address an outbreak of Black Band Disease (BBD) that has been affecting *Montipora* corals on the north shore of Kauai since 2012
- DAR has provided partial support for a PhD student at the Hawaii Institute of Marine Biology (HIMB) to map the disease and correlate its presence with environmental variables
- This phase of research showed a weak correlation between BBD and temperature, the outbreak is most active during the warm summer months
- No correlation was found between BBD and visibility, organic composition of sediment, or proportion of sediment
- A treatment to stop the disease using a marine epoxy putty has proven effective, but is not efficiently used in large areas

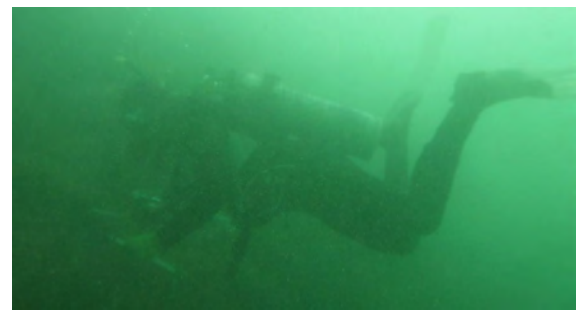


(left) BBD on a *Montipora* coral. Photo credit: C. Runyon (UH)

(above) BBD abundance on the north shore of Kauai showing spatial variability

Next Steps:

- Coordinate joint DAR-USGS workshop in March 2015 to further investigation into environmental drivers of the BBD on Kauai
- Continue to provide briefings and updates to local community members, county officials, and additional partners



Reef Response Next Steps

- Continue to connect with managers via the Coral Reef Response group, hosted by the TNC Reef Resilience Network
- Finalize revised Rapid Response Contingency Plan (RRCP) to reflect DAR protocols and Standard Operating Procedures
- Integrate Aquatic Invasive Species (AIS) protocols into revised RRCP
- Write and implement Reef Response Program strategy and funding plan

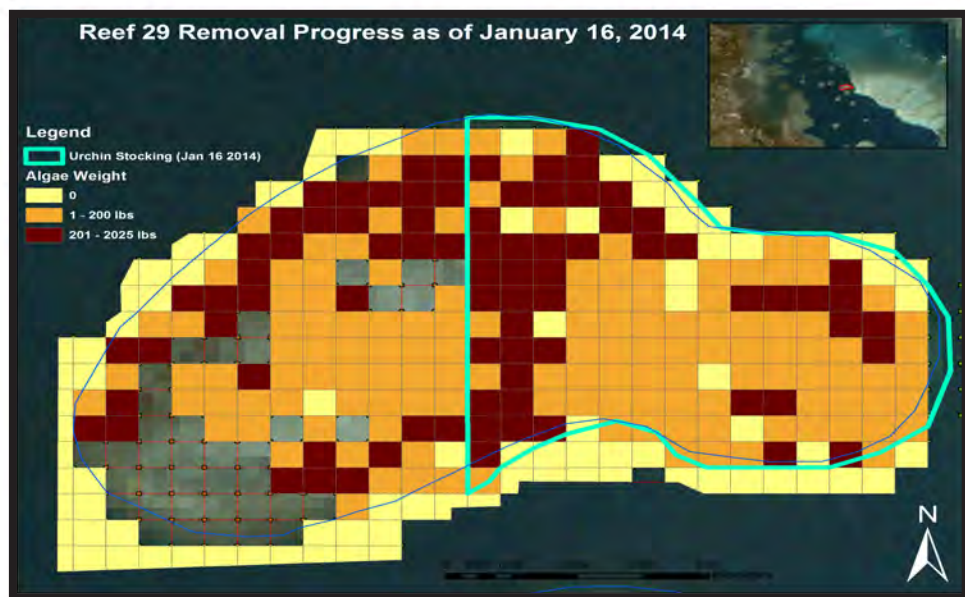


Kaneohe Bay Reef Restoration - January 2014

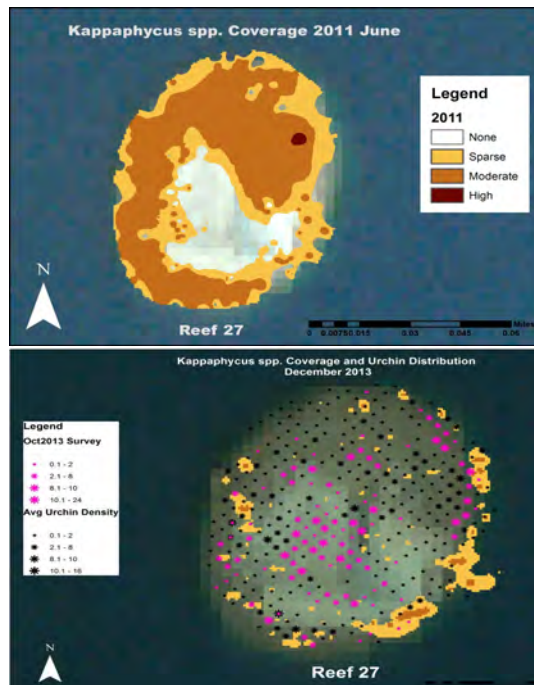
The fragile patch reef system in Kaneohe Bay is suffering a critical infestation from a number of alien seaweeds, Smothering seaweed (*Kappaphycus/Eucheuma* sp.), and Gorilla Ogo (*Gracilaria salicornia*). Using mechanical removal and hatchery raised native sea urchins, DAR is able to show preliminary success in the control of this alien seaweed.

2013 Accomplishments

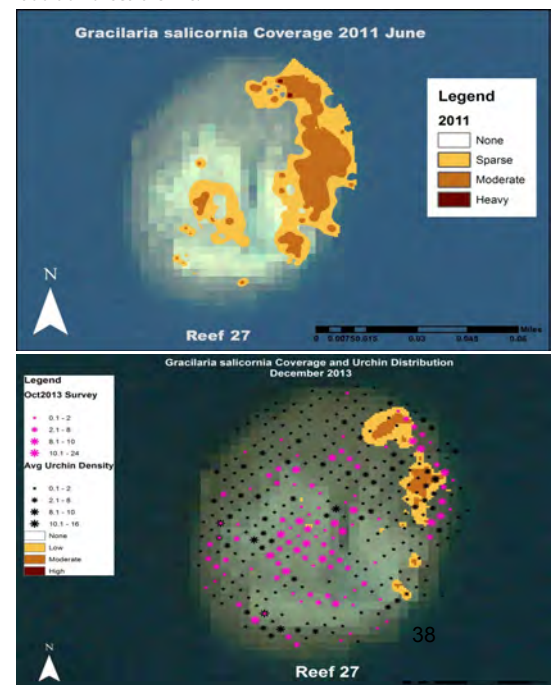
- Removed 92,907 pounds of alien invasive algae from 12.5 acres of reef using the Super Sucker barge.
- Outplanted 93,000 hatchery raised collector urchins to Kaneohe Bay.
- Conducted 30 monitoring events across 6 different patch reefs to measure the coral, algae, urchin, and fish composition before, during, and after algae removal and urchin outplanting. (see otherside for results)
- Participated in 23 outreach events to raise awareness about invasive algae and how to prevent its spread.



Map of *Kapp/Euch.* coverage on Reef 27 before (June, 2011) and after (Dec, 2013) mechanical removal and addition of hatchery raised collector urchins.



Map of *Gracilaria salicornia* coverage on Reef 27 before and after addition of hatchery raised urchins. *Gracilaria* is not targeted by Super Sucker so reduction in coverage is completely due to addition of sea urchins.



The Super Sucker Fleet:

Senior
13x25' Barge

Junior
8x16' Barge

Mini
5x8' Mini Barge

Operated and managed by:

Div. of Aquatic Resources
1151 Punchbowl St. Rm 330
Honolulu, HI 96813

state.hi.us/dlnr/dar
dlnr.hawaii.gov/ais

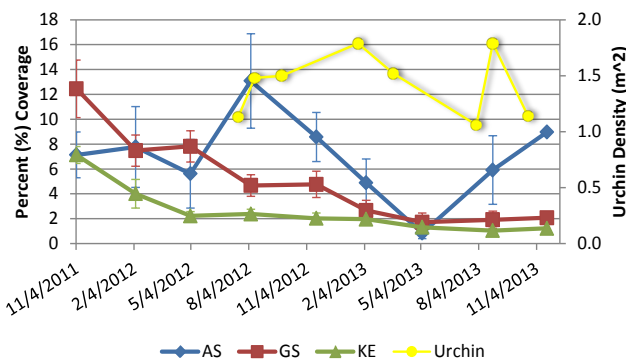
2013 Preliminary Results

During 2013, the field team used the Super Sucker barge to remove invasive algae (*Kappaphycus/Eucheuma sp.*) from Reef 29 and began to stock with hatchery raised urchins. Reefs 26/27 had algae removed prior to 2013 and continued to receive urchins as needed, while Reef 28 was used as a control reef. Urchin density was maintained between 1-2 urchins/m².

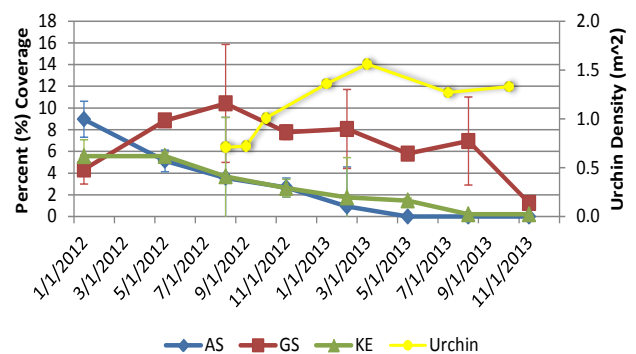
Reef 26 saw a steady decline of invasive algae through May, 2013, but recently saw a large increase of Prickly seaweed (*Acanthophora spicifera*), while *Gracilaria salicornia* and *Kappaphycus/Eucheuma* continue to be maintained at less than 3%. Reef 27 saw a continuous decline with all invasive algae maintained at less than 2%.

Reef 29 had previously been removed of invasive algae in late 2012, but urchins were not available at the time to efficiently stock this reef. A second removal event commenced August 2013 and will finish February 2014. This reef is over three times the size of 26/27 and has much higher density of *Kappaphycus/Eucheuma sp.* This reef is 50% stocked with hatchery raised urchins and expected to be fully stocked by May, 2014.

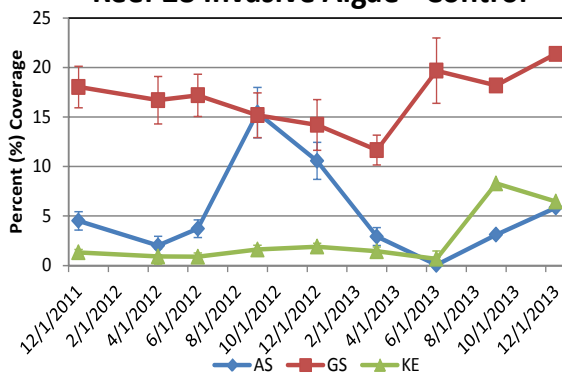
Reef 26 Invasive Algae



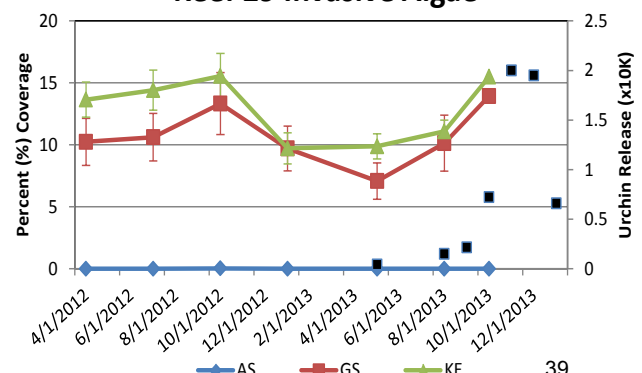
Reef 27 Invasive Algae



Reef 28 Invasive Algae - Control



Reef 29 Invasive Algae



Day Use Mooring Buoy-Phase III

Social Science Research Institute, Sept.30, 2014

PROJECT OVERVIEW

Phase II of the Day Use Mooring Buoy (DMB) project showed no clear consensus within DLNR on a cohesive DMB program framework that would effectively oversee and improve the current program into a solid component of the state's ocean recreation management.

Phase III focused on building consensus on the adoption of formal DMB Program within Division of Boating and Ocean Recreation (DOBOR).

PROJECT GOALS AND OBJECTIVES

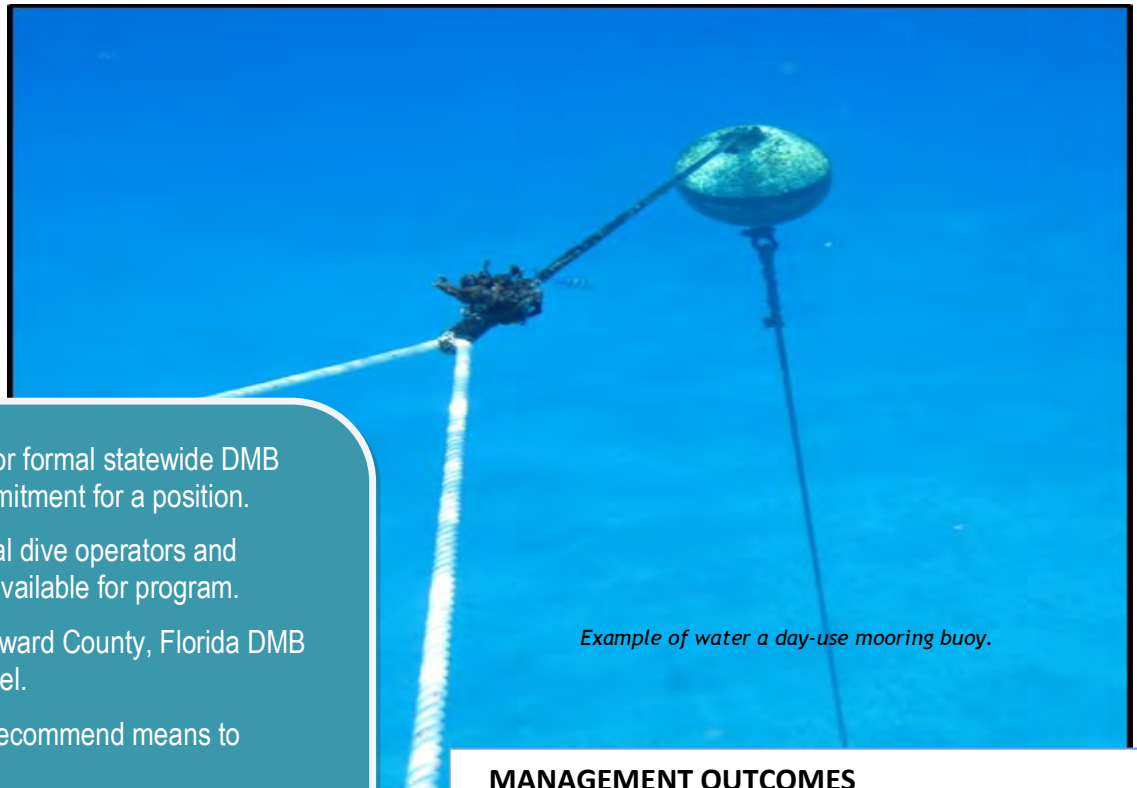
Goal: Reduce anchor damage and trampling on coral reefs by utilizing Day Use Mooring Buoys (DMB) and other means by 2020.

Objective: Create a functional DMB Program within the Department of Land and Natural Resources. Specifically;

1. Find consensus on key decision points.
2. Create DMB operational plan.
3. Research DMB liability issues.
4. Create DMB operation plan.

RESULTS

- Secured funding for formal statewide DMB program and commitment for a position.
- Identify commercial dive operators and estimate funding available for program.
- Agreed to use Broward County, Florida DMB program as a model.
- Researched and recommend means to reduce liability.
- Drafted an Operational Plan detailing activities and timeline for first 3 years.
- Developed contractor checklist.



Example of water a day-use mooring buoy.

MANAGEMENT OUTCOMES

DOBOR will implement an exemplary, industry standard DMB network that will address the needs of boaters and manage impacts to marine resources at popular dive/snorkel locations.

Meta-Analysis of Reef Fish Data in Hawaii: Biogeography and Gradients of Human Impacts

Alan Friedlander, Fall 2013

PROJECT OVERVIEW

This project conducted a comprehensive examination of reef fish assemblage structure across Hawaii. 25 data sets representing more than 25,000 individual fish surveys since the year 2000 were synthesized. The results show clear, distinct bioregions across the archipelago that give us a better understanding of reef fish macroecology and have important implications for management at the regional scale. The findings from this study also highlight the negative impacts of human population pressure on reef fishes, particularly around Oahu and Maui.

PROJECT GOALS AND OBJECTIVES

One of the major obstacles to wise management of coral reef fisheries is the lack of sound information on population abundance at spatial scales commensurate with the uses of these resources. This information is critical to developing sustainable fisheries management strategies, improving management of existing Marine Protected Areas (MPAs), designing future MPA networks, and aiding in the development of comprehensive marine spatial planning.

This study, for the first time, has synthesized all these data sets into a single and spatially comprehensive database in order to characterize reef fish assemblages around Hawaii while controlling for habitat, wave exposure, and geographic influences.

RESULTS

- Over one-quarter of the species (27%) examined in the MHI appeared to be depleted below 10% of unfished abundance, while 42% were below 25% of unfished abundance
- Endemic species were much more common at the northern end of the chain
- The traditional Hawaiian district or moku was used as a unit of spatial stratification. Moku explained 63% of the variability in resource fish biomass
- Biomass of resource species was negatively correlated with human population pressure among mokus.
- Older MPAs had the highest resource fish biomass while newer MPAs had fewer numbers and smaller sizes of resource fishes.



MANAGEMENT OUTCOMES

A more holistic approach that includes community-based management, expansion of the MPA network with a greater emphasis on no-take reserves, improvements to current fisheries regulations including enhanced enforcement efforts, and finally a greater emphasis on marine education and ocean awareness are necessary.